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Ordnance Technical Staff Number

ARMY ORDNANCE

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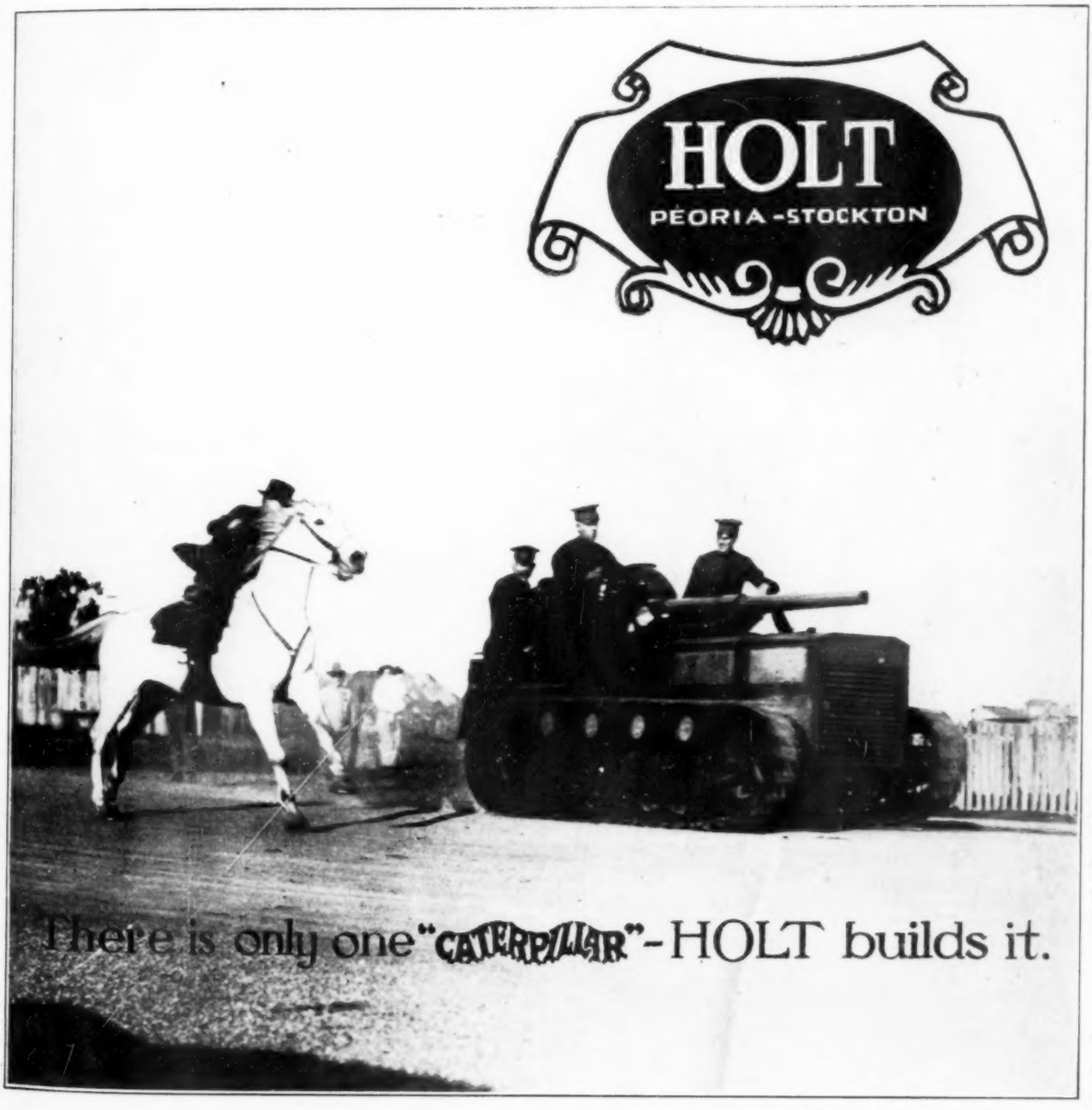
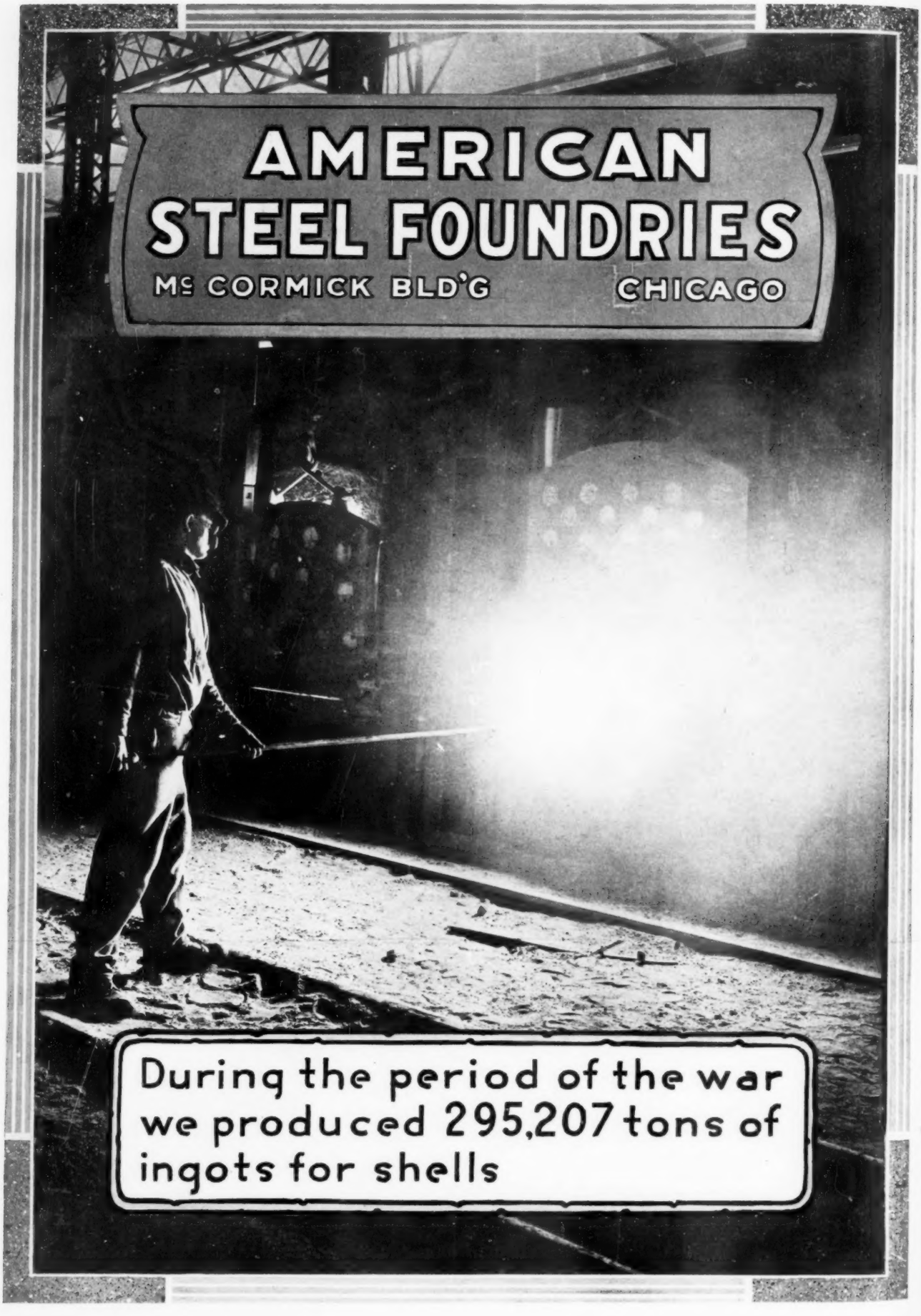


~THE·JOURNAL·OF·THE·ARMY·ORDNANCE·ASSOCIATION:~

Peace Work on War Weapons—"One Fifty-Five" vs. "Cent Cinquante-Cinq, G. P. F."


AMERICAN
STEEL FOUNDRIES
Mc CORMICK BLD'G CHICAGO
During the period of the war
we produced 295,207 tons of
ingots for shells

ARMY ORDNANCE

THE JOURNAL OF THE ARMY ORDNANCE ASSOCIATION

Pledged to Public Service in Effecting Industrial Preparedness for War as Our Strongest Guarantee of Peace

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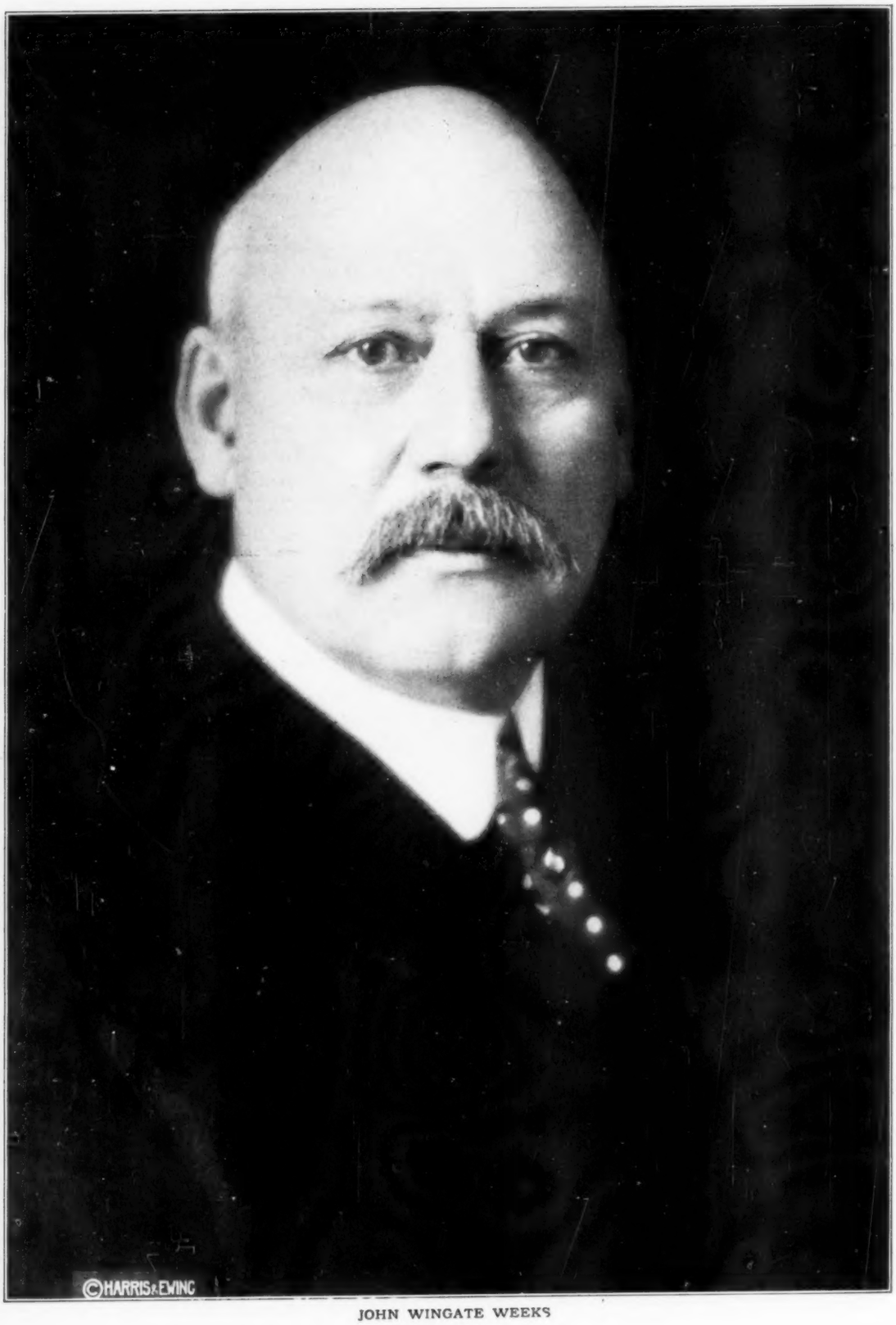


JOHN WINGATE WEEKS
Secretary of War

Peace Work on War Weapons

By

COLDEN L'H. RUGGLES
Member A. O. A.

UNTIL twenty or twenty-five years ago, when the military establishment was small and appropriations limited, the work of the Ordnance Department itself was correspondingly small and the Chief of Ordnance then could give a fairly competent oversight to designing and development work. All drawings and projects for new development and research were approved by him personally. Although the opinion of the line in new development work was sought by application to individual officers from time to time, there was, on the whole, little or no systematic reference to such officers for suggestions as to improvements in ordnance. One reason for this was that there were then no chiefs of the line or using services and accordingly no authoritative line opinion to be obtained. Furthermore, individual officers of the line had, as a rule, given much less attention to desirable improvements in ordnance than had the ordnance officers specifically charged by law with its development.

General Ruggles

This condition continued practically unchanged until the entrance of the United States into the World War, except that a Chief of Artillery (later changed to Chief of Coast Artillery) was provided by law in 1901, and that there was an increasing tendency on the part of the Ordnance Department to seek the assistance of the line or using services in passing upon new war material, as shown by the appointment of Coast and Field Artillery officers on the Ordnance Board stationed at the Sandy Hook Proving Grounds for the test of new artillery material, and the appointment of line officers on boards to assist ordnance officers in passing upon new types of small arms and machine guns. Adequate personal supervision of new designs, development work, and research by the Chief of Ordnance, however, became increasingly difficult, and, finally, when the United States entered the World War, such supervision became an utter impossibility.

When the present Chief of Ordnance was appointed, in May, 1918, he found a going organization of the Ordnance Department which he could not change radically without serious interference with production of munitions. He, therefore, had to content himself with such modifications of the existing organization as were possible and which he thought absolutely necessary at that time, leaving to a later date a complete reorganization of the Department in accordance with his ideas of what would be most desirable. Shortly after the signing of the Armistice, plans for the complete reorganization of the Department were prepared, and the new organization was put into full effect on February 1, 1919. The organization then prescribed, with minor modifications, is that which obtains to-day.

The policy of the Chief of Ordnance is to furnish the line, or using services, with armament which meets with their approval.* He believes that these services are the proper judges of the tactical requirements of the armament used by them, while the Ordnance Department is the proper judge as to whether the desires of the using service in any given case can be met and, if so, how they shall be met in an engineering construction designed by the Ordnance Department. Also he holds that it is the duty of the Ordnance Department to look beyond the present needs of the using

[*Maj. Gen. C. C. Williams, Chief of Ordnance, United States Army, read the manuscript of this article before publication, and approved the above statement of his policy.—ED.]

services and to discover or invent, if possible, new weapons of war more effective than those used in the past, even though the using services do not feel the need for the new devices. He realizes that most of the progress of the world in the mechanical arts has been due to the vision of inventors who were not discouraged by skepticism as to the utility of the new methods or devices proposed by them; but, while he considers it the duty of the Ordnance Department to anticipate the needs of the using services, his policy is not to attempt to force anything new upon those services. The duty of the Ordnance Department in this connection is fulfilled when the new devices are presented to the using services for trial and for acceptance or rejection in their best judgment. In the carrying out of his policies, he believes that a real instead of a nominal check should be exercised over designing officers to prevent the enthusiasm of a designer running beyond desirable limits in inaugurating and carrying on research and development work or in carrying into a design too many of his own individual ideas which may not have been sufficiently well considered or tried out, or which may not meet with general approval. He believes firmly in the principles that the *suitability of a new device shall be determined by officers not responsible for its design.* He desires, further, that the details of a new design shall include as many as possible of the features found convenient and desirable by the using services.

To insure the execution of his policies in this regard, the Chief of Ordnance in his reorganization order of January, 1919, provided for a Technical Staff whose principal duty is to exercise for the Chief of Ordnance, over the research, design and development work of the Ordnance Department, a supervision such as, in the early history of the Department, it was possible for the Chief of Ordnance himself to exercise personally, but which for many years past has not been physically possible because of the increased responsibilities of the Ordnance Department and the rapid advance in specialized knowledge required in the design of modern war materiel. Among the specific duties prescribed for the Technical Staff in the reorganization order of January, 1919, were the following:

(*a*) To keep informed of the trend and progress of ordnance development at home and abroad.

(*b*) To recommend to the Chief of Ordnance new and experimental types of ordnance which, when approved by the Chief of Ordnance, will be developed and designed by the Manufacturing Service.

(*c*) To approve for the Chief of Ordnance design and manufacturing specifications and drawings and studies covering types and experimental matériel, and to approve texts of revision of all matériel in which the functioning will be affected.

(*d*) To have charge of and administer all proving grounds operated as such by the Ordnance Department.

(*e*) To conduct or approve programs of all trials of pilot ordnance matériel except shop tests, firing tests at arsenals, and preliminary road tests, and, wherever possible, to attend important trials of ordnance in other services in this country and abroad.

(*f*) To witness the test of all type matériel and report to the Chief of Ordnance whether such matériel is satisfactory for issue for service test by the using service.

(*g*) To develop plans for wider publication and distribution of ordnance engineering data, and to encourage discussion and developments of its theoretical principles.

(*h*) To confer, as the representatives of the Chief of Ordnance, with the Line and General Staff of the Army regarding types of ordnance desired to be developed.

(*i*) To arrange for the assignment to the Technical Staff of qualified officers of the Line of the Army and such civilian engineers as may be found advisable.

(*k*) To conduct research work in ballistics and metallurgy and to prepare general metallurgical specifications.

(*l*) To approve all programs for experimental and research work initiated for the purpose of improving ordnance matériel.

The provision for the assignment to the Technical Staff of qualified officers of the Line of the Army is for the purpose of insuring that the point of view of the using services shall be kept in mind at all times from the inception of a given project through the detailed processes of design to the test and acceptance of the materiel at the proving ground prior to its delivery for final trial in actual service by the using organization of the Line.

To carry out the duties of the Technical Staff there have been organized within it four technical divisions and an Ordnance Committee. Each of the technical divisions is composed of ordnance officers and civilian engineers who have an expert knowledge of the subjects under the jurisdiction of the division, with an ordnance officer of experience at its head. These technical divisions are:

(1) Ordnance Theory, Instruments and Metallurgy Division;
(2) Ammunition and Explosives Division;
(3) Artillery and Automotive Division;
(4) Aircraft Armament and Small Arms Division.

Each of these divisions supervises the work of the Technical Staff with respect to the subjects and materiel falling within the jurisdiction of the division, which are described in general terms by the name of the division.

The Ordnance Committee is advisory to the Chief of the Technical Staff, who is also its chairman. This committee considers and recommends action upon matters affecting materiel designed for or intended to be issued to the service coming within the jurisdiction of the Technical Staff, and upon such other matters as may be referred to it by the Chief of the Technical Staff. The members of the committee, for consideration of all subjects brought before it, are:

A naval officer, representing the Bureau of Ordnance, U. S. Navy;

The Chief of Manufacture, office of the Chief of Ordnance, or his representative;

The chiefs of the divisions of the Technical Staff, and officers of the line or using services who represent the chiefs of their services on the committee;

The Secretary of the committee (an officer of the Technical Staff).

Other members of the committee are the chiefs of the divisions of the Manufacturing Service or their representatives, for consideration of subjects pertaining to their divisions; and the heads of sections of the various divisions of the Technical Staff for consideration of subjects pertaining to their sections.

The operation of the Technical Staff (except its liaison work with engineering societies, the administration of the proving grounds, the direction of research work in ballistics and metallurgy and the preparation of general metallurgical specifications) is essentially by committee action, since one of the principal reasons for the creation of the organization is to prevent what may be described as a personal or one-man influence on design and development work, and to substitute therefor a thorough and mature consideration of all research, new projects, design and development work by a body representative of all the interests concerned—that is, of the designing, *reviewing* and using services. To facilitate the work of the Ordnance Committee, the following permanent sub-committees have been appointed:

(1) Sub-committee on Railway and Seacoast Artillery, for consideration of all questions relating to guns and mounts, railway matériel, etc., for railway and seacoast artillery.

(2) Sub-committee on Mobile Artillery, for consideration of all questions relating to guns and mounts for mobile artillery, including self-propelled mounts, anti-aircraft guns and mounts, and trench mortars.

(3) Sub-committee on Mobile Artillery, for consideration of all ques-

tions relating to ammunition for cannon, including propellants and shell fillers, bombs, pyrotechnics, hand and rifle grenades.

(4) Sub-committee on Small Arms and Small Arms Ammunition, for consideration of all questions relating to small arms, machine guns, 37 mm. guns, and small arms ammunition, but not ammunition for 37 mm. guns.

(5) Sub-committee on Aircraft Armament, for consideration of all questions relating to aircraft armament.

(6) Sub-committee on Tractors, for consideration of all questions relating to tractors and trailers.

(7) Sub-committee on Tanks, for consideration of all questions relating to tanks.

(8) Sub-committee on Metallurgy, for consideration of all questions relating to metallurgy, both ferrous and non-ferrous.

(9) Sub-committee on Instruments, for consideration of all questions relating to optical instruments, including sights, range-finders and all fire-control instruments.

(10) Sub-committee on Mathematics and Dynamics, for consideration of all questions of theory connected with ordnance matériel, such as interior ballistics, theory of design, etc.

(11) Sub-committee on Standardization of Specifications, for the standardization of specifications under instructions of the War Department.

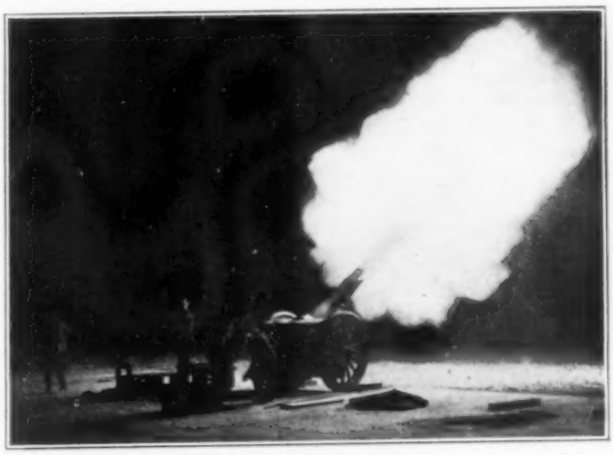
Each sub-committee, except the sub-committee on standardization of specifications, is composed of the chief of the division of the Technical Staff having jurisdiction over the subject, as chairman; of the chief of the division of the Manufacturing Service interested, or his representative; of the representatives of the using services interested; and of the head of the section of the Technical Staff having jurisdiction over the subject. The sub-committee on standardization of specifications consists of the Chief of the Ordnance Theory, Instruments and Metallurgy Division of the Technical Staff, as chairman; of representatives from other divisions of the Technical Staff and Manufacturing Service of the Ordnance Department; and representatives from interested supply services other than the Ordnance Department. The chairman of each sub-committee is authorized to call before the sub-committee such persons in addition to the members of the sub-committee as may assist in the discussion and determination of questions before the sub-committee.

All matters to be acted upon by the Ordnance Committee, including approval of drawings and specifications, the approval of research or new lines of development work, programs for same and programs for test of materiel of new types, if they do not originate in a division of the Technical Staff, are, as soon as received, referred to the division charged with such matters for the Technical Staff. Here the matter is examined and investigated, additional data secured, if necessary, and the subject prepared for presentation to the proper sub-committee for report and recommendation to the Ordnance Committee. This report is prepared in type and signed by all members of the sub-committee.

It will be seen from the organization of the sub-committees that there are represented on each all the organizations of the army whose interests are involved in a proper determination of the questions before the sub-committee. The view of the designer is presented by the chief of the division of the Manufacturing Service or his representative, and the view of the using service or services by the representatives of those services. The view of the representatives of the using service is not necessarily the opinion of the individual officer who presents it; the opinion presented by that officer is the official opinion of his arm as determined by the chief of that arm.

In former years such an official opinion was not obtainable, and the ability to obtain it now is one of the great advantages to the Ordnance Department that have resulted from the appointment of chiefs of combatant arms, whose duty it is to ascertain the best opinion of their arms and to establish fixed and consistent policies for those arms. The officers and engineers of the Technical Staff sitting on sub-committees as representatives of the Technical Staff, which is the reviewing organization of the Ordnance Department, are in a position to act as umpires between the desires of the using services and the inclinations and limitations of the designer or inventor.

All matters in doubt or in disagreement are thoroughly discussed, investigated and settled in sub-committee, so that, when the report of the sub-committee is presented for final action and recommendation by the Ordnance Committee, it represents the well-digested conclusion of a number of experienced officers and engineers representing all services whose interests are legitimately concerned. The reports of sub-committees have been surprisingly unanimous, considering the number of interests involved and, as a consequence, little or no discussion is required in the Ordnance Committee, which is thus enabled to conduct its business with dispatch. Such discussion as does take place in the Ordnance Committee is usually for the purpose of informing its members, other than those on the sub-committee making the report, on the subject matter under discussion. Sometimes, however, discussion in the Ordnance Committee



Proof-firing at Night

has brought out points or information not considered by the sub-committee and has resulted in referring the matter back to the sub-committee for further consideration.

The approval of the Ordnance Committee is a recommendation to the Chief of the Technical Staff that the action determined on in the committee be carried out. When the committee action is approved by the Chief of the Technical Staff, the chief of the proper division of the Technical Staff issues the necessary instructions to the Manufacturing Service, the proving ground, or whatever agency is required to execute the instructions. The action of the Chief of the Technical Staff, in all matters coming under the jurisdiction of the Technical Staff, is the action of the Chief of Ordnance. The Chief of the Technical Staff must keep himself informed at all times as to the policies of the Chief of Ordnance, and is responsible to the latter that all approvals given are in conformity with his policies. In case of doubt in any particular case, it is the duty of the Chief of the Technical Staff to seek definite instructions from the Chief of Ordnance before acting on the matter.

While the majority of the subjects handled by the Technical Staff are those which affect materiel designed for or intended to be issued to the service, there are a number of subjects which do not fall within this category, among which may be mentioned engineering and research problems

which do not affect the tactical use or features of the materiel. In cases of this kind of minor importance, the matter is handled exclusively by the proper division of the Technical Staff; in cases of this kind of greater importance, the matter is considered by the proper one of the sub-committees mentioned above, except that, as the subject does not primarily interest the line or using services, the representatives of those services are not present; and the report of the sub-committee is submitted direct to the Chief of the Technical Staff for approval without going through the Ordnance Committee.

Subsequent to the formation of the Ordnance Committee in the Technical Staff of the Ordnance Department, the War Department directed that technical committees be formed in all the supply bureaus of the army, to perform for those bureaus essentially the same functions as the Ordnance Committee performs for the Ordnance Department, and it was directed also that representatives of the using services be designated to attend the meetings of these committees. The Ordnance Committee is, therefore, the technical committee of the Ordnance Department.

The technical committees of the supply services form important agencies in the general scheme of the War Department for the adoption of new and improved types of articles for service use. Formerly, general policies upon which the development of new and improved materiel to be furnished the army shall proceed, were formulated by boards of officers appointed by the War Department and representative of the using and designing services. The recommendations of such boards to become effective had, of course, to be approved by the War Department. Since the establishment of technical committees in the supply bureaus, the War Department has decided that the general policies upon which the development of new and improved materiel to be furnished the army shall proceed, shall no longer be prepared by boards of officers appointed by the War Department, but shall be formulated by the technical committees of the supply bureaus charged with the development. The general policies so prepared must receive the approval of the chiefs of the supply bureaus and using services concerned and the final approval of the War Department before becoming effective.

In order to visualize in detail the steps* that must be taken before a new type of ordnance is adopted as a standard for the U. S. Army, let us suppose that a new type of gun is to be developed for the mobile artillery. The need for such a new weapon, let us suppose, has been shown in the World War. Since this weapon will differ from the adopted standards of the U. S. Army, its development must be approved by the War Department. In order to secure this approval, the matter is considered by the Ordnance Committee and a recommendation made that a gun having the characteristics desired be developed by the Ordnance Department. If the Chief of Ordnance approves, he forwards this recommendation of the Ordnance Committee, with his approval, through the chief of the arm for which the gun is intended, to the War Department. If the latter chief also approves the project, which he will do undoubtedly, since his representatives on the Ordnance Committee voted in favor of it, it will in all probability be approved by the War Department and the paper containing the recommendation will be returned to the Chief of Ordnance with instructions to undertake the development.

When this paper is returned to the Ordnance Department, it will be sent to the Technical Staff. The Chief of the Artillery and Automotive Division of the Technical Staff will then call a meeting of the sub-committee on mobile artillery for the purpose of preparing general specifications showing the principal requirements that should be fulfilled by the new gun. Usually these requirements will include a limit for the weight of the gun, the caliber of the gun, the weight of the projectile, the range to be obtained, the kind of breech mechanism to be used; possibly, also, a limit to the length of the gun, the twist of the rifling, the number of lands of the rifling, and any other features which, in the opinion of the sub-committee, should be included in the design. The sub-committee will then submit its report to the Ordnance Committee, recommending that the new gun be designed in accordance with the general specifications prepared by the sub-committee. When this report is approved by the Ordnance Committee and the action of the Ordnance Committee is approved by the Chief of the Technical Staff, instructions will be sent by the Chief of the Artillery and Automotive Division of the Technical Staff to the Manufacturing Service to design the gun in accordance with the general specifications approved by the Ordnance Committee. If there are funds available for the work, it will be commenced at once by the Artillery Division of the Manufacturing Service. If funds are not available, an item covering the estimated cost of the development will be included in the estimates to be submitted at the next session of the Congress. Estimates for experimental and development work of this kind are prepared by the Manufacturing Service and approved by the Ordnance Committee before being submitted by the Chief of Ordnance.

Assuming that funds are available for the development of the gun, the next step is the preparation of pencil studies by the Artillery Division of the Manufacturing Service. During the preparation of these studies, the designing officer may have informal conferences with the other members of the sub-committee on mobile artillery, or he may ask that a sub-committee meeting be called to settle some points which may have arisen during the preparation of the studies on which he desires a decision. When pencil studies have been completed which, in the judgment of the Artillery Division of the Manufacturing Service and the Chief of Manufacture, meet the requirements laid down by the Ordnance Committee of the Technical Staff, they are submitted for the approval of the Technical Staff and are acted upon by the sub-committee on mobile artillery and the Ordnance Committee. Upon the approval of these studies by the Technical Staff, the preparation of general and detail drawings is undertaken by the Artillery Division of the Manufacturing Service. When these drawings are completed to the satisfaction of the Artillery Division of the Manufacturing Service and the Chief of Manufacture, they also are submitted for the approval of the Technical Staff and are acted upon by the sub-committee on mobile artillery and the Ordnance Committee, as in the case of the pencil studies.

During the preparation of these drawings, the designing officer may have informal conferences with the other mem-

*The description of the action of the sub-committee and the Ordnance Committee in connection with the development of a gun is based, for sake of simplicity, on the assumption that no questions will arise affecting other than the gun proper. As a matter of fact, however, this will rarely or never be the case, and there are many questions which must be decided which vitally affect both the gun and the ammunition to be used in it, and which will involve the application of the theories of interior and exterior ballistics. Actually, therefore, the general specifications for the gun will be prepared by the sub-committees on mobile artillery, ammunition, and mathematics and dynamics, acting together as one sub-committee; and thereafter during the subsequent steps in the developmnt of the design and the test of the gun this joint sub-committee action will be had whenever conditions or circumstances render it advisable.

bers of the sub-committee on mobile artillery, or he may ask that sub-committee meetings be called to render decisions on points which may develop during the progress of the design.

When the drawings are approved by the Technical Staff, the manufacture of a type or pilot gun (or guns) will be undertaken by the Artillery Division of the Manufacturing Service. When the guns are completed at an arsenal or private manufacturing plant, and the necessary shop tests and adjustments made, including, when feasible, preliminary firings at an arsenal, they are sent to the proving grounds for exhaustive test by the Technical Staff to determine whether they fulfill all the requirements laid down by the Technical Staff and are, in its judgment, satisfactory weapons for service use. The program for this test is prepared by the sub-committee on mobile artillery and approved by the Ordnance Committee and the Chief of the Technical Staff; and it is the special duty of the sub-Committee to witness these tests and to report to the Ordnance Committee, whether the guns have passed a satisfactory test, and if not, whether they should be rejected outright or certain modifications made in them to correct defects developed by the test. If further modifications or a redesign is required, the procedure is essentially the same as has been described in the development of any new type.

When the guns have passed a satisfactory test in the judgment of the Ordnance Committee, as approved by the Chief of the Technical Staff, the Chief of Ordnance will report that fact to the War Department and request that the necessary instructions be issued by the War Department for a service test of the guns by the line or using organization. For service tests, a considerable number of the experimental type of article will usually be issued. If the service test is not satisfactory, the Ordnance Department will be directed by the War Department to continue the development with a view to correcting the defects brought out in the service test. If, however, the service test is satisfactory, the new type of gun will be adopted by the War Department as the standard type for the U. S. Army.

At the risk of repetition, it is thought well to call attention of the continuing influence of the sub-committee of the Ordnance Committee on every step taken in the development of the gun from the inception of the project to the final adoption of the gun as a type by the War Department, and to the fact that this sub-committee is composed of a representative of the designing organization of the Ordnance Department (the Manufacturing Service), of representatives of the reviewing organization of the Ordnance Department (the Technical Staff), and of representatives of the line or using organization of the army.

The following table shows the number and classification of the subjects considered by the Ordnance Committee during the calendar year ended December 31, 1920:

Small arms (including bayonets, sabers, scabbards, etc.)	73
Machine guns (including automatic rifles)	48
Small-arms ammunition	45
Mobile artillery guns (including infantry accompanying guns, infantry howitzers, sub-caliber tubes and trench mortars)	91
Mounts (exclusive of self-propelled mounts for mobile artillery)	27
Self-propelled mounts	28
Ammunition for mobile artillery (exclusive of fuzes)	70
Fuzes for mobile artillery	23
Anti-aircraft artillery	22
Railway mounts	15
Fixed mounts for seacoast defense	16
Guns for railway and seacost artillery	26
Ammunition for railway and seacoast artillery (exclusive of fuzes)	29
Fuzes for railway and seacost artillery	7
Range finders and fire-control instruments (including sights)	52
Bombs	45
Bomb sights	9
Other aircraft armament	23
Grenades	14
Pyrotechnics	8
Tanks	23
Tractors	18
Trailers	14
Standardization of specifications	10
Total	736

Included among the subjects listed in the above table are fifteen programs for investigative and research work, of which three are being prosecuted at colleges throughout the United States; thirty-two programs for test firings, including range firings and tests of automotive materiel; and seventy inventions.

The Technical Staff is charged with liaison with the engineering societies of the country. In the pursuance of this duty it has arranged with the Society of Automotive Engineers to appoint a committee from that society to act as advisors of the Ordnance Department in connection with its designs and tests of automotive materiel. This committee consists of eight members of the Society of Automotive Engineers, including the president and past presidents of the society and the general manager thereof, all appointed by

Maneuvering Test in Soft Ground

the society; of the Chief of the Technical Staff, of the Chief of the Artillery and Automotive Division of the Technical Staff and the chiefs of the Artillery and the Tank, Tractor and Trailer divisions of the Manufacturing Service, and of their assistants engaged in automotive work. This committee meets approximately every three months, and the members representing the Society of Automotive Engineers have rendered, by their advice, most valuable assistance to the Ordnance Department in its design of automotive equipment.

As a result of conferences between the Technical Staff and members of the American Society of Mechanical Engineers, the society has been interested in the establishment of an ordnance section in the society. A petition to establish this section, signed by 172 members of the society, was approved by the Council of the society on December 10, 1920. It is expected, through this section of the American Society of Mechanical Engineers, to keep the members of the society informed at all times of the progress of ordnance design and development, to ask the assistance of the members in solving technical problems of design and production as they arise, and particularly to interest the society in the broad and vitally important question of what measures should be taken adequately to prepare this nation

for the prompt and sufficient supply of munitions in time of war. Following the establishment of an ordnance section in the American Society of Mechanical Engineers, and based upon this section as a type, it is hoped to interest other engineering societies to the extent of having an ordnance section established in each of them. It is believed that the discussions of the ordnance problem before these societies will result in the greatest benefit to the Ordnance Department and to the country by developing a well-considered and practical program of munitions preparedness.

[General Ruggles was in command, at the beginning of the war, of the Sandy Hook Proving Ground, and was President of the Ordnance Board. Upon his recommendation, first made before the war, the proving ground was moved to a larger and better site at Aberdeen, Md. He prepared the plans and superintended the construction of the proving ground, which commenced operations on January 2, 1918, at which time he was assigned to command of both Sandy Hook Proving Ground and Aberdeen Proving Ground.

On March 4, 1918, he was ordered to Washington and made Chief of the Supply Division of the Ordnance Department, which was responsible for the storage and supply of all ordnance matériel to the Army in the United States and for shipment of ordnance supplies to the A. E. F.

On March 28, 1918, he was appointed Chief of the Inspection Division of the Ordnance Department, which performed the inspection of all ordnance matériel manufactured in the United States and Canada. The work of inspection included also ballistic testing at all proving establishments except at the Aberdeen Proving Ground, Sandy Hook Proving Ground, and Savannah Proving Ground. Testing work at these proving grounds was performed under the Engineering Bureau, but the suitability of all matériel tested there for service was passed upon by the Inspection Division. It also operated eight other temporary proving grounds established throughout the country for the ballistic testing of ordnance matériel being furnished for the troops abroad. When the Armistice was signed, inspection was being performed in approximately 8,000 manufacturing plants working on ordnance contracts.

He was appointed Brigadier General, Ordnance Department, on August 8, 1918. He remained Chief of the Inspection Division until after the signing of the Armistice, when, following the reorganization of the Department, he was made Chief of the Technical Staff, Ordnance Department, which position he now holds.—ED.]

Discussion

H. W. Alden

Vice-President, Timken-Detroit Axle Co.

I have read General Ruggles' article with a great deal of interest, and it seems to me that the Ordnance Department has emerged from the war with what is probably a more proficient organization for future development than any other department of the army.

I cannot conceive of a better arrangement for co-ordinating Ordnance activities with general civilian engineering and production facilities than that which has been worked out, and as I have been a member of the Society of Automotive Engineers' Ordnance Committee for a year, I speak from personal knowledge.

It has been a matter of keen personal pleasure to have worked with the members of the Ordnance Technical Staff on the various problems which have come before us, and I do not doubt that the attitude of mutual confidence will be of considerable assistance to the Ordnance Department in times of peace and of vast assistance in time of war.

C. F. Hirshfeld

Chief of Research Department, Detroit Edison Co.; Chairman, Ordnance Section, American Society of Mechanical Engineers

Our social organization in this country is so new when regarded from the viewpoint of human history that we have not yet discovered all that it implies. The founders of this form of society undoubtedly regarded government and all governmental functions as of primary importance, and they further undoubtedly assumed that each citizen would exhibit a very keen interest in the actions of a government which he had assisted in placing in authority. They also undoubtedly assumed that government would be regarded as a common problem instead of the problem of a single class or social stratum and that each citizen would assume and carry his share of the burden.

As a matter of fact, things have not worked out in just this way. We have developed to a great extent the spirit of "Let George Do It" when it comes to government and functions associated with government. This is really quite human and is to be expected under any form of social organization which offers equal or nearly equal opportunities for personal advancement and personal gain. Each of us is very apt to go his own sweet way, putting his maximum effort into the acquisition of wealth, social position, learning, or any other thing which particularly appeals to him as an individual; paying taxes grudgingly, but as a matter of necessity; criticizing the acts and motives of elected and appointed officials, but accepting them unless they are altogether too bad or too brazen.

Now, the maintenance of an army is a governmental function, and history shows that we have been perfectly satisfied to let our elected and appointed representatives worry over the problem for us. Only when we have actually gone to war has the state of the military establishment caused us any personal concern. We then invariably profess great surprise over the results of our disinterested policy.

If the Technical Staff succeeds in doing nothing more than maintaining an active interest in Army Ordnance on the part of representative members of the different Technical Societies of this country, it will accomplish something well worth doing and of immeasurable benefit to the nation in any future war. The technical brains of the country, as represented in these societies, can undoubtedly supply a certain amount of engineering experience and a certain amount of technical knowledge and skill. But, to my mind, such assistance is of minor importance. The relationship should react to keep the ordnance officers alive to commercial methods, improvements, and requirements and, on the other hand, should keep the necessity for adequate provision for ordnance development squarely before some of the best and most representative commercial and technical minds of the nation. These things seem to me of far more importance than a mere exchange of technical knowledge.

It has been demonstrated that it is possible to recruit and train men for military service much more rapidly than the equipment required to make them available for service can be produced. Moreover, the present trend of warfare is in a direction which must cause greater and greater discrepancies in this respect as time goes on. If such facts are properly brought to the attention of men of the caliber and number found in our technical societies, and if they are repeatedly hammered into their consciousness by frequent contacts with those dealing daily with such problems, I feel certain that we will ultimately find the nation ready to do that which may be necessary to bring about proper development and production of the material of war, and that we will ultimately devise the ways and means to accomplish this purpose.

Lt. Col. A. J. Dougherty

Infantry, U. S. A.

Until the plan of Gen. C. L'H. Ruggles, Ordnance Department, had been approved by the Chief of Ordnance and the Ordnance Committee established, there existed within the War Department no satisfactory machinery by means of which the requirements of the line and the manufacturing possibilities of the various supply departments could properly be co-ordinated. The line "kicked" occasionally when a supply department issued some article not entirely satisfactory and attempts were then made to correct the defect, generally after a supply of the defective article had been purchased.

In justice it must be admitted that, except in the office of the Chief of Coast Artillery, no body of line officers existed whose duty it was to gather opinion and inform the supply departments of line requirements in reference to matériel. Even where individual line officers gave this matter thought they had no conception of the problems of development, manufacture and supply.

The net result was an inability of the supply departments to obtain line views on the requirements for any article, except through the costly process of equipping the army with it. Once equipped with an unsatisfactory and inefficient article the line was doomed to use it until worn out; an end generally accomplished as quickly as possible, thus causing much waste of government funds, in addition to chronic friction between the line and supply services.

The creation of the Ordnance Committee composed of representatives from the Ordnance Department, and from the office of each Chief of Arm, has, so far as concerns Ordnance, finally effected complete and satisfactory liasion between line needs and supply possibilities.

Within each Arm there is a board of officers stationed at a post, with troops, where exceptional opportunities exist for gathering line opinion, and for subjecting pilot material to service tests. This Board is constantly studying existing equipment and gathering line opinion from officers of experience, with a view to formulation of general requirements for entirely new equipment or for improvements in that already existing. These requirements are sent to the Chief of Arm and taken up with the Ordnance Committee by his representative, an officer of much line experience who is in constant contact with ordnance activities.

The General Staff having approved a development program, the representatives of the arms concerned have full voice at the meet-

ings of the Ordnance Committee, where details are worked out which result finally in production of a small lot for field tests by the arm interested. Formerly when articles were sent out to troops for try-out, no one took much interest in the test, the importance of which was not realized by the average company officer. The article, more frequently than not, rested in the company store-room until the captain was "jacked up" for not having rendered his report. He promptly consulted his first sergeant and "got-off" a perfunctory opinion which was seven-eighths guess. Now the same equipment would be sent to the board of the interested Arm and its test by troops would be followed throughout by an expert whose official reputation depends on the thoroughness with which he performs this particular work. The results are placed before the Board and recommendations made to the Chief of Arm. The entire matter is then taken up with the Ordnance Department through the representative of the Chief of Arm on the Ordnance Committee. The result is that an article is known to give efficient performance before it is produced in quantity.

The Ordnance Committee, in addition to eliminating a long standing source of friction between the Ordnance Department and the line, will also undoubtedly save large sums of government moneys thus more than justifying the salaries paid to officers engaged in this work.

A. M. Mattice

Advisory Engineer, Remington Arms Co., Inc.

The Army Ordnance Association is fortunate in having presented to it such a clear and concise exposition of the organization, functions and methods of the Technical Staff of the Ordnance Department as is contained in General Ruggles' article. The organization described is, of course, a peace-time one, forming a nucleus for the greatly expanded organization which would be found necessary in war-time.

Maneuvering Test, Engine Submerged

Firing Test of Self-Propelled Mount

In peace-time, the dealings of the Ordnance Department with outside manufacturers are comparatively unimportant; but when the industries of the country are mobilized in war-time, the relations between the Department and the manufacturer are necessarily so close and of such vital importance to the nation that nothing should be left undone to secure the needed co-operation. The fostering of such co-operation is, in fact, one of the principal functions of the Army Ordnance Association.

The enormous expansion of the Ordnance Department during the World War necessarily entailed the employment of a personnel of varying degrees of experience and efficiency, and of a system which in the beginning was more or less tentative and had to be modified somewhat from time to time. It would have been a miracle if, with such a hastily assembled organization, everything had worked as smoothly as could have been desired; and much praise is due to the organizers that things worked as smoothly as they did. In an organization charged with such important affairs, the leading executives are naturally engaged in the larger matters of policy, and many minor troubles do not get to their attention. It is natural also that some varieties of trouble can become known to the organization only through the contractors to whom the troubles manifest themselves. It is only with a view to possible elimination of one source of such trouble in the next that I venture to call attention to a difficulty which forced itself on the Government and on contractors alike during the recent war:

In any organization one of the essentials to be provided for is complete harmony in dealings with outside parties; that is, that the members of the organization itself shall not work at cross purposes in such dealings. In an old established organization of moderate size, where principals and assistants are working in harmony, it is not difficult to so arrange the work that correspondence with clients or customers will be carried on without friction. But where the organization is large, divided into many departments, and with frequent additions to the personnel, it not infrequently happens that there are unintentional and embarrassing clashes.

No matter how careful a system for co-operation there may be, the personal equation, or plain human nature, will assert itself more or less frequently, sometimes with disastrous effect. It is to guard against such possible lapses that in commercial organizations various expedients are resorted to. In some establishments it is arranged that all correspondence with each important customer or client shall pass through the hands of, or be reviewed by, one person in the organization, who keeps in touch with all phases of the transactions with such party, and is thus able to head off any nascent discord. By lack of some such precaution during the late war there were numerous cases of trouble, great and small, which easily might have been prevented. To illustrate the kinds of cases referred to, I will cite an example:

A manufacturer was making large quantities of bayonets for the government, under a fixed-price contract, and everything had been running smoothly for a long time. Then a hitch occurred somewhere and shipping instructions ceased, although bayonets continued to be manufactured, inspected and packed for shipment. The Inspector of Ordnance at the factory continued to ask for shipping instructions, but none arrived. This was kept up for nearly two months, until some two hundred thousand bayonets had accumulated, in which the manufacturer had about half a million dollars tied up. The deadlock was not broken until the manufacturer received from Washington a letter which in no gentle terms took him to task for failing to meet his contract production when bayonets were urgently needed. A reply to the effect that all available space in the manufacturer's works was filled with packed bayonets, for which vain attempts had been made to get shipping instructions, started things moving, and telegraphic instructions arrived the next day. A sequel to this affair which might have seemed humorous to anybody but the manufacturer was that, when payment was made for the bayonets, something over twenty thousand dollars was deducted as liquidated damages for delay in meeting the contract schedule for deliveries. How the mixup started the manufacturer never knew, but it probably was caused by some conflict of responsibility or authority.

Here is another instance that occurred in another factory of the same manufacturer. He was manufacturing a large number of rifles under a cost-plus contract. Then came an order for an additional number, followed by other orders which increased the quantity of rifles by about half a million rifles and a large number of spare parts. These additional orders, in the form of permanent orders, letters and telegrams, which came at various times during several months, kept the manufacturer's purchasing department busy securing the necessary material. Then, one day came a telegram from Washington cancelling one of the orders, which resulted in feverish haste to cancel orders for materials and to head off shipments of materials in transit. This was followed the next day by a telegram cancelling another order, which was followed by other telegrams cancelling other orders until all the additional orders had been cancelled. An inquiry from the manufacturer, as to the desired disposition of the large quantity of material which had been secured, brought from Washington the information that it was not intended to curtail production at all, but that the cancellations of orders were only technical, with a view to embodying them all in the supplement to the main contract. Then the manufacturer's purchasing department got busy again to procure materials, while the works management had the more difficult task of replacing the men who had been laid off and had secured other jobs.

This unfortunate affair, which caused a serious break in production, like the bayonet episode, had a sequel, or rather several sequels. Several weeks after the unintentional cancellations of orders all payments to the manufacturers were stopped because the cancellations had

automatically cancelled the corresponding allotments of funds. After this had been straightened out temporarily, a supplement to the main contract, providing for the increased quantity of rifles, was sent to the manufacturer for execution. This supplement, however, was dated some time subsequent to the cancellation of orders and contained no provision for payments for work done prior to the date of the contract. Upon inquiry, the manufacturer found that payments for prior work could not be made under such a contract, and he therefore returned the supplement for revision. This supplemental contract, however, did not get through the process of revision and re-approval before the Armistice, and so had to be validated under the Dent Act, with the consequent complication of claims and subsequent statutory awards.

The above-described incident could easily have been avoided by means of provisional cancellations, showing on their faces their intention, instead of the telegraphic absolute cancellations without explanations. It is probable that the trouble started from some inexperienced subordinate misunderstanding his instructions, and zealously carrying out his instructions as he understood them. Both of the incidents cited—the lack of shipping instructions for bayonets and the unintentional cancellation of orders for rifles—were not only causes of vexatious delays to the government and expense to the manufacturer, but their correction occupied valuable time of men whose services were needed in productive work.

Both of these incidents, together with others which came under the writer's observation, could have been avoided if all the correspondence with each contractor had been required to pass the review of one person who would thus be acquainted with all of the ramifications of each contract, from the inception of the negotiations to the completion of the contract, and so would be able to catch errors before they resulted in trouble. In fact, in such a large expansion of organization, hastily effected, it is to be expected that "bad breaks" will occur unless some method of constant check on co-operation between departmental organizations be adopted.

Col. George B. Williams

Cavalry, U. S. A.

When the Ordnance Committee of the Technical Staff was first conceived, the Cavalry Service and the Infantry Service had no heads of their branches in Washington to represent them in matters of this kind. Consequently, the representative of the General Staff on this committee took it upon himself to arrange consideration of these two arms in all matters affecting their equipment. Shortly thereafter the General Staff obtained authority for an officer of the Cavalry Service to become a member of the committee.

On June 4, 1920, Congress approved an Act providing the cavalry and the infantry services each with an organization in the War Department, having at its head a major general of each arm, to whom could be referred matters affecting these two combat branches. The office of the Chief of Cavalry was thus established July 1, 1920, and thereafter the cavalry has been able to have direct representation on the Ordnance Committee. The officer so detailed is authorized to represent his chief in all matters affecting his service and to offer suggestions affecting the suitability of any particular article for his arm. There existed at this time at Fort Riley, Kans., a Cavalry Board through whose medium the office of the Chief of Cavalry was enabled to have an agency for testing in the field types of equipment, and through whose reports opinions could be rendered on all matters affecting the armament, equipment, and supply of the cavalry. Through this board, therefore, the office of the Chief of Cavalry is enabled to develop a close liaison between the cavalry soldier in the field and the Ordnance Department, the procurement and manufacturing agency for a most important part of that equipment.

The correlation of these two services—on the one hand the Using Service and the other the Procuring Service—exists along the following lines:

(a) The Cavalry Service, through the Chief of Cavalry in Washington, acts as an adviser to the Chief of Staff in all matters affecting the cavalry. For the purpose of showing the relationship between the cavalry and the Ordnance Committee, let us assume that this Using Service desires a carbine to replace its present weapon—the Springfield rifle. To meet this need, the cavalry would set forth the general requirements which the specifications for this carbine should contain; only those requirements being considered which affect the tactical use of the weapon, and which would include, in general, its weight, length, range, rate of fire, etc. The Chief of Cavalry would forward this statement of requirements for a carbine to the General Staff, who, in turn, would refer it to the Ordnance Department.

(b) The Ordnance Department would check these general requirements over, and, through its organization, make up the drawings to accomplish the task, write its specifications, and present them to the Ordnance Committee. When approved, one of its manufacturing units would be instructed to make such a weapon, and, upon its completion, to have it factory tested. Accomplishing this, the matter then again would be in the hands of the Ordnance Committee, before whom it would be presented, and, assuming that the test was satisfactory from a technical point of view, the Ordnance Committee would then recommend a certain number to be manufactured to be sent to the Cavalry Board for field test. If, after this field test, the gun has proven satisfactory, and the type is approved by the General Staff, this weapon would then become an article of issue.

From the above it will be seen that every consideration is given to the Using Service, which is so important in the proper development of equipment for that service. The problem given involves no points of issue between the Using Service and the Procurement Service. However, should differences of opinion exist, this matter is settled by the Ordnance Committee to the satisfaction of all concerned.

All matters affecting the requirements of production, etc., entering into the design of an article of equipment, or the availability of raw materials, should be presented by the Ordnance Department; on the other hand, questions of usability should be presented by the Using Arm. It is the fundamental duty of the Ordnance Committee to correlate these two sets of requirements so that the needs of the two services in question are met.

While the above example gives to the reader one method for development of new equipment, this particular routine does not always obtain. Often it is the case that new improvements in design are first presented by the Ordnance Department, and after obtaining the views of the cavalry the article then may be developed and changed, if necessary, to meet its tactical use. In every case the Ordnance Committee is the agency whereby all interested services are consulted.

In general, there are many problems taken up by the Ordnance Committee which are not of vital interest to the cavalry. However, if all agencies of the army are not kept informed of what each is doing, the development work of one will be lost on the others. Through the medium, therefore, of this committee one of its most important functions obtains in that all new ordnance matériel of each Using Service is presented and discussed in open conference. In this way the question of new policies in the tactical development of equipment for any particular Using Service can be co-ordinated to the development work of the Ordnance Matériel of the other Using Services. To this end the Ordnance Committee has fulfilled a very great need, for, through its medium, there has developed the closer co-operation and understanding which is so necessary in the fulfillment of any program involving more than one agency.

Col. Robert E. Wyllie

Chief, Equipment Section, Operations Division, War Department, General Staff

From the standpoint of the General Staff I have no hesitancy in saying that the establishment by General Williams of the present Ordnance Committee is one of the most important forward steps that have been taken in the army in the development of matériel. We all know the feeling which existed in former times, how the line accused the ordnance of providing equipment which it, the line, did not want and the ordnance in their turn complained that the line demanded the impossible. The meetings of the Ordnance Committee have removed all such friction, there is a better understanding on both sides. The Ordnance Department is acquainted with the tactical requirements, while the line has a proper appreciation of the difficulties which beset the designer and producer, and the supervisory work of the Operations Division of the General Staff is made immeasurably easier. When the using and producing services agree the approval of the Secretary of War becomes almost a perfunctory matter, consequently the work of the Operations Division now amounts to hardly more than keeping such track of development as will assure it that the services do agree and that the matériel developed is satisfactory to both the user and producer. All other supply agencies have now adopted this committee plan with the most excellent results, but the credit for its initiation is due absolutely to the present Chief of Ordnance.

Joint Meeting

Ordnance Section, American Society of Mechanical Engineers

and

Army Ordnance Association

Rock Island Arsenal, Illinois

May 27 and 28, 1921

For details see page 281, this number

Shore Batteries *vs.* Battleships

Notes on Firings Against the Old *Massachusetts*, Pensacola, Florida

By

W. B. HARDIGG

Member A. O. A.

DURING the past year, the U. S. Battleship ex-*Massachusetts* was dismantled by the Navy Department and was turned over to the Chief of Coast Artillery for use as a target for Seacoast Artillery. The old *Massachusetts* was laid down in 1891, launched in 1893, and put into commission in 1896. She was partially reconstructed in 1905. She had a displacement of 10,288 tons; waterline length, 358 feet; beam, 69 feet, and draught of 28 feet. Her main belt armor (Harvey) was 18 inches to 15 inches, 17-inch bulkheads, 3-inch deck, 17-inch barbettes. All of the armament and the serviceable fixtures worth salvaging were removed before the vessel was towed to Pensacola Harbor to serve as a target, but the armor was left intact.

In December, 1920, the *Massachusetts* was grounded on a sand shoal about 4,000 yards off Old Fort McRae and almost ½ mile from the ship channel leading into Pensacola Bay. The ship was placed so that when she rested on an even keel on the sand the depth of water was equivalent to her normal draft, and so that her port main-belt armor was exposed to the fire of the guns in the coast defenses of Pensacola. Shortly after the vessel was grounded a heavy storm caused her bow to swing about the stern as a pivot through an angle of approximately 60 degrees and gave her a list to seaward of 15½ degrees. The new presentation of the ship prevented the attack of belt armor from the shore guns.

Prior to the grounding of the ship the Coast Artillery Board drew up a program of firings to be conducted against her. The program was approved by the proper authorities and the necessary ammunition and equipment sent to Fort Barrancas for conducting the firing tests.

The program included firings from a 12-inch gun fixed battery with armor-piercing shot and shell; a 12-inch fixed mortar with deck-piercing shell both inert and explosive; a 12-inch railway mortar with deck-piercing shell, and from a 12-inch railway gun with 12-inch armor-piercing shell. In addition, 3-inch and 5-inch star shells were to be tested at night.

Early in January the Coast Artillery Board, consisting of the following officers: Maj. F. H. Smith, C. A. C., president; Maj. Quinn Gray, C. A. C.; J. H. Pirie, C. A. C.; L. B. Bender, Signal Corps, members, and W. B. Hardigg, Ordnance Department, temporary member, proceeded to Fort Barrancas to supervise the firings.

The program was gotten under way as soon as the weather permitted, the first firings being made from the 12-inch fixed mortar with 1,046-pound shells. Three hits were obtained, one entering the forward stack at its juncture with the superstructure, emerging below the berth deck and tearing a rent of about 30 square feet area in the stack at the point of egress, continuing its way through the boiler room, and, so far as could be determined, entirely through the hull. The other two fell between the stacks on the port side of the center line of the ship. These rounds also perforated the ship.

The next series was fired from the 12-inch fixed gun battery at short mid-range. Five hits with A. P. shells were made—three forward, one in main belt and one aft. The

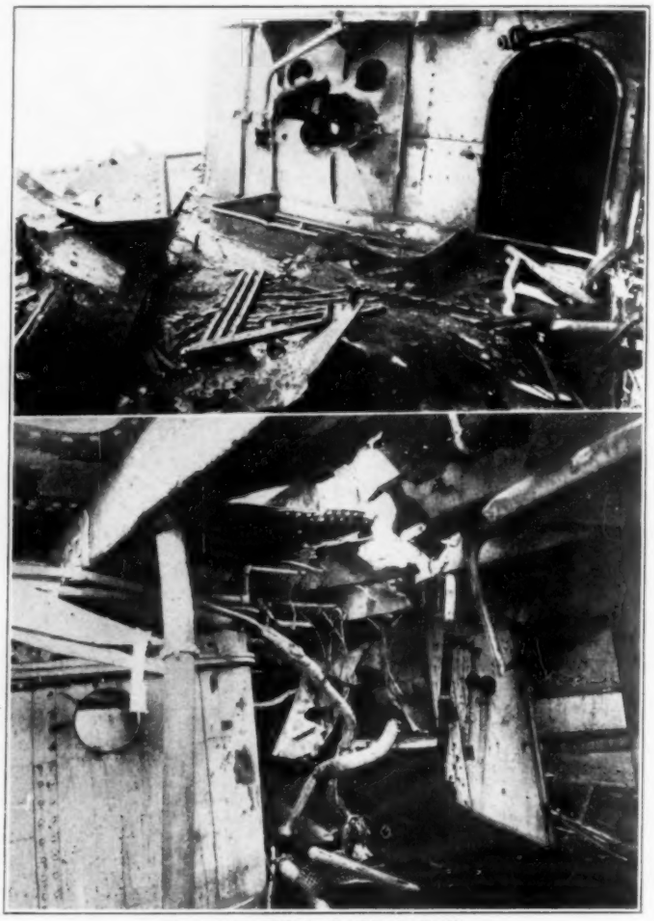
Damage to Superstructure by Fragments from a Shell

hits forward wrecked the forward compartments on the berth deck, cutting the bulkheads and arching up the main deck, wrecking the anchor-chain locker and starting a fire in some timber work left in the vessel. The hit aft wrecked the ammunition-handling facilities of the port 8-inch turret, completely wrecked the water-distilling installation of the ship, and distorted the plates, turret barbette and base of cage mast. The shell bursts cut dozens of unprotected communication lines and did considerable superficial damage. The hit on the main belt was at a very unfavorable angle and caused practically no damage.

Armor-piercing shot were next fired from this battery. The main belt was presented at such an oblique angle that no hits were placed in it. Three hits were placed in the forward turret and two in the superstructure. The hits on the turret were not fair hits; the first, being a very oblique hit at the top of the turret, cut a groove in the turret armor and passed to sea. The second ripped open the main deck for a distance of about 12 feet and struck the turret casemate at an oblique angle. The armor plate

struck was slightly displaced. The third hit cut open the berth deck, passed through the supporting beams for a distance of about 18 feet, and caused a considerable displacement of the armor plates struck when the projectile "key-holed" without penetration. In the superstructure, one shot cut through practically the entire width of the bridge deck, the other penetrated the forward stack and cut the main deck for a distance of about 30 feet, doing slight damage to ammunition hoist on the starboard side. The projectile burst and did superficial damage to thin plating about the barbette of after 8-inch turret.

Firings from the 12-inch railway mortar were next made. Weather conditions were unfavorable, and as the range was considerable from this piece, some trouble was encountered in the range adjustment. When visibility improved, however, the fire was adjusted, though a 50-mile gale was blowing aloft. Two hits were placed between the smoke stacks, one to port and one to starboard side of center line. The hit to port perforated the ship, while the hit to starboard burst just inside the belt armor. The decking on the berth deck was blown up over a considerable area. The presence of water rendered it impracticable to determine the damage below decks from this hit.



Destructive Effect of a Single Shell

Additional firings from 12-inch fixed mortar were then made. Two hits were placed between the stacks near the center line of the ship. These projectiles penetrated below protective deck and presumably perforated the hull of the vessel.

Firings were next made from the 12-inch railway gun. Two hits forward were made before the firings were suspended. One hit burst on the main deck, the slope of which was but little different from the angle of fall of the projectile. This hit blew a large hole in the main deck and did some superficial damage. The other entered the side of the vessel just forward of the collision bulkhead, penetrated this bulkhead, which was practically detached from the sides of the vessel due to previous shell bursts, penetrated the berth deck and burst near the orlop deck, which was submerged. The detonation of this projectile opened up the seams in the side of the vessel at the orlop deck for a distance of about 20 feet, blew up the berth deck-plates over the area of the detonation, put an additional arch in the main deck and opened up a seam several inches wide between main deck and side plates of vessel for a distance of about 20 feet.

In addition to the firings from the large caliber guns, star shell were fired over the vessel from 3-inch batteries at about 4,500-yard range and from a 5-inch gun at about 6,000-yard range. The shell functioned well, and when properly placed, the ship stood out boldly to observers at ranges under five thousand yards, but at greater ranges and when the line of vision from the observer to the star did not pass through or very close to the vessel, the vessel was not clearly outlined.

The purpose of the tests conducted was to determine the effectiveness of seacoast ammunition from reserve supplies against the vessel, and to confirm or to cause changes in certain policies of design of seacoast ammunition, and to determine the relative value of several types of seacoast defense weapons.

The shifting of the vessel due to action of the wind and waves prevented the attack of the main belt with any hope of perforation, so that the question as to whether the armor or projectile of two decades ago overmatched was not settled. The projectiles allotted for this part of the test were made shortly after the close of the Spanish-American War.

The firing of the high-angle weapons clearly indicated that vessels of the *Massachusetts* type have no adequate armor defense against this type of attack.

The long-range firings indicated that a large angle of fall is a great advantage in the attack of armored vessels.

In general, the firings against the old battleship confirmed conclusions drawn from the information gleaned from study of reports of damage done by gun-fire during the World War. We can now feel more fully assured that the policies laid down for future design and supply of seacoast guns and ammunition are sound. Furthermore, it was shown that war vessels in an attack on our land defenses are exposed to speedy destruction as soon as they come within range of the curved-fire guns.

During the past three years great progress has been made in the design, manufacture and testing of armor-piercing projectiles. American manufacturers have produced 12, 14 and 16-inch projectiles which have passed, satisfactorily, tests under specifications requiring penetration of armor-plate in condition for effective detonation at angles of impact up to 25° from normal.

The ballistic qualities of these projectiles have also been so improved that, at the present time, it is possible to say that America can produce, and has produced, armor-piercing projectiles which are, so far as is known, the best in the world.

War-Time Production of Optical Munitions

By

F. E. WRIGHT
Member A. O. A.

[The writer of this article, Lt. Col. Wright, Ord. R. C., was closely identified with the manufacture of optical glass and optical instruments during the war. From April, 1917, to May, 1918, he was in charge of the development of the manufacture of optical glass at the Bausch & Lomb Optical Company plant at Rochester, N. Y. He was the Army Representative on the Military Optical Glass & Instrument Section of the War Industries Board; chairman of the Army Commodity Committee on Optical Glass and Instruments under the Director of Purchases and Supplies; and later was assigned to the instrument section of the Artillery Division of the Ordnance Department and made responsible for optical matters. From January to June, 1919, he was occupied chiefly with the design and construction of experimental instruments and sights for use in the control of fire by long-range seacoast batteries. He was President of the Optical Society of America during 1918 and 1919. During the war he had exceptional opportunities to study the many problems which arose in connection with the optical industry and its war-time development and the conclusions stated in the present article are the outcome of these experiences.—ED.]

THE optical glass and instrument situation during the World War had much in common with that of the production of other kinds of munitions. In all branches of manufacture similar difficulties arose because of the lack of trained personnel, of manufacturing and transportation facilities, and of proper co-ordination of the many diverse elements involved. These difficulties have been emphasized repeatedly in articles and reports, and, were it not for the fact that the optical industry is in some respects unlike any other, comments on its war-time development would be superfluous and of no real interest.

The only justification for an article on the production of optical munitions is to emphasize certain lessons which were deeply impressed upon the minds of a few, but which, in general, are hardly appreciated and may soon to be forgotten. The purpose of the present article is to interpret some of the difficulties encountered during the war in the production of optical glass and of optical instruments rather than to describe them in detail.

Optical instruments are essential in modern military operations not only for detecting details of distant objects but also for directing artillery fire; in case of war they must be available in adequate quality and quantity for use by the field forces. For the many types of optical instruments required by the different branches of the service much good optical glass of several different types is needed; trained operators and ample plant equipment are also necessary for the production of the desired lens systems.

When we entered the war in April, 1917, optical glass of satisfactory quality was not being manufactured in quantity in this country. The methods for its manufacture were inadequately known; no one with first hand knowledge of manufacturing processes was available; and it was a serious question whether we would be able to produce optical glasses of satisfactory quality in quantities sufficient for the needs of the Army and Navy. At that time five different plants, spurred on by dire necessity because the customary sources of European supply had been closed several years before, were trying to produce optical glass in this country but with only indifferent success. These plants were the Bausch & Lomb Optical Co. at Rochester, N. Y.; the Bureau of Standards at Pittsburgh, Pa.; Keuffel & Esser of Hoboken, N. J.; the Pittsburgh Plate Glass Co. at Charleroi, Pa., and the Spencer Lens Co., at Hamburg, N. Y.

Approximately a ton of good optical glass per day was required to meet the needs of the Army and Navy. The total production, however, did not exceed 4 tons per month of optical glass of indifferent quality. To avoid a real calamity both the rate of production had to be increased rapidly and the quality of the glass improved in order to meet the conditions of high precision imposed by fire-control instruments. It was realized that to attain this degree of precision a group of men accustomed to research problems similar to those met with in optical glass manufacture should be put on the job. Fortunately there existed at that time in this country a scientific research laboratory with a personnel experienced, not in the manufacture of optical glass, but in the fundamental principles underlying its manufacture. In the emergency the Government, through the National Research Council, appealed to this laboratory for assistance. The appeal was favorably received and on April 16, 1917, the resources of the Geophysical Laboratory of the Carnegie Institution of Washington were offered to the Government for the period of the war, the expenses to be borne by the Carnegie Institution without aid from the Government; the offer was accepted and the problem of optical glass manufacture was attacked as would any similar research problem have been attacked. The research investigator is constantly facing new and unexpected problems in his own work and develops, as a result, resourcefulness and adaptability as well as the faculty of proceeding directly to the essentials of a problem. Shortly after the work was entered upon, the more important defects of the existing practice were discovered by the scientists and appropriate remedies were devised to overcome them. The total contribution of the Geophysical Laboratory to this undertaking was approximately $200,000, but the results attained justified the expenditure.

A great variety of problems arose in connection with the manufacture of optical glass. These included problems of factory organization, of factory operation, of the procurement and transportation of raw materials, of glass melting pots and of coal; also the more difficult task of obtaining hearty co-operation from certain manufacturers who were vitally interested, but who extended formal co-operation only with a strong under-current of passive resistance. Co-operation of this kind leads to innumerable delays and unfulfilled promises and must be treated both tactfully and firmly to accomplish the desired results. In the game of war-time production everything is subordinated to the one object of producing the desired material within a definite period; the military program requires munitions of many different kinds and it is the task of the manufacturing forces of the country to furnish these on

time. Everything else, including expense, is subordinated, for the moment, to speed; as the manufacturing program gathers momentum, the obstructionists and half-hearted co-operationists either learn their lesson or they are eliminated. Under the stress of high speed production suggestions and plans for increasing the rate of production are made and if, after adequate test, these prove to be satisfactory, they are introduced into the factory routine. Many of these suggestions come from outside plants. Under the emergency conditions manufacturers of broad vision are willing to exchange, with their peace-time competitors, information on factory practice, with the result that over the entire country the manufacture of munitions soon attains a state of efficient operation.

The procurement and the transportation of the raw materials for optical glass required constant attention throughout the war period. At first it was necessary to locate satisfactory sources of supply for these materials. Specifications had to be stated with reference both to the optical glass requirements and to the chemical manufacturing possibilities. Many chemical manufacturing plants were visited by members of the Geophysical Laboratory before the details of the supply of raw materials were properly arranged. The problem of transportation continued to be a constant source of trouble. Innumerable delays in the shipment of raw materials occurred; in many instances the General Munitions Board, and later the War Industries Board and the Production Division of the Ordnance Department rendered valuable service in expediting railway traffic. It is inevitable, however, that in a war-time emergency railway traffic is overtaxed. Under these conditions it is the duty of each manufacturer of munitions to stock, as early as possible, adequate quantities of supplies so that the inevitable delays in the transportation of additional supplies do not retard production. At one time during the early months of the war forty different manufacturers were actively assisting in the manufacture of optical glass, chiefly in the supply of the necessary raw materials and of glass melting pots. In the development of melting pots of high chemical and thermal resistance the Bureau of Standards aided materially.

The question of fuel and gas for the glass melting furnaces and other operations became serious during the coal shortage of the winter of 1917-1918. When it is realized that the glass plant at the Bausch & Lomb plant alone consumed 33 million cubic feet of illuminating gas per month, a quantity sufficient to meet the needs of a city of 80,000 inhabitants, the scale of its fuel consumption and of the difficulty of meeting the situation adequately is apparent.

From April to December, 1917, the efforts of the Geophysical Laboratory were concentrated chiefly on the development of the manufacture of optical glass. By December, 1917, the production of pot optical glass had reached 40 tons per month at one plant (Bausch & Lomb); the processes of manufacture had been mastered for the most part; and subsequent efforts were directed chiefly to an increase in the manufacturing capacity for optical glass throughout the country. Early in December the Geophysical Laboratory took charge of the Spencer Lens Company plant, and, as a result of hearty co-operation on the part of this firm and of a modern though small plant, was able to produce satisfactory glass from the first melt on. Late in December the Geophysical Laboratory assumed practical charge of the Charleroi plant of the Pittsburgh Plate Glass Company. This plant was an old plate-glass plant in which the Pittsburgh Plate Glass Company had installed 16 single-pot glass-melting furnaces of a blast furnace type and had tried unsuccessfully for several years to produce a satisfactory product. At the time the Geophysical Laboratory group arrived at the plant several of the problems involved to place the plant on a running basis were not at first apparent, especially the lack of temperature-control in the glass melting furnaces and the impossibility of establishing such control with the system then in operation. To remedy this each furnace had to be equipped with individual blowers and many fundamental changes effected before satisfactory production could be attained. This required some months and proved to be a task of considerable difficulty partly because of a lack of appreciation on the part of this company of the significance of the factors underlying the manufacture of optical glass and of the fact that optical glass is not plate glass, nor is a plate-glass maker necessarily a competent maker of optical glass. In retrospect it is now evident that better progress would have been made, more glass produced, and much money saved, had either a new optical glass plant been built or, for example, the plant of the Spencer Lens Company been expanded rather than the attempt made to remodel an old plate-glass plant. Experience proved also that in the manufacture of optical glass it is better to start with new hands than with plate or other glass-makers, who are necessarily prejudiced and do not readily change their attitude of mind toward certain factory operations. The conservatism and inflexibility of the ordinary factory hand can be appreciated only through actual manufacturing experience.

It would seem to be a wise policy for the Government in time of war to concentrate its efforts on two plants for the manufacture of optical glass rather than three or more. In two plants properly situated adequate quantities of optical glass can be produced to meet all needs. In this connection, however, the increased destructiveness of airplane bombs and other demolition agencies should be considered. In case an existing glass plant is offered for conversion to the manufacture of optical glass its adaptability for the purpose should be carefully considered before the conversion is sanctioned.

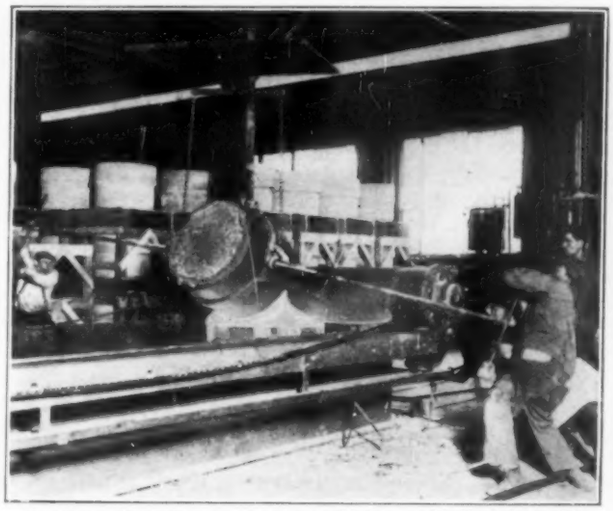
The first government contract for optical glass was placed in October, 1917. At that time there were no inspectors available for the inspection of optical glass. Accordingly it was necessary to ascertain first the relative competency of the different methods available for the inspection of optical glass and to devise new methods in case the existing methods were found to be inadequate or otherwise unsuitable. A satisfactory routine for inspection was thus established. Army Ordnance inspectors were then trained to the task and later Signal Corps and Navy Inspectors. The first deliveries on this contract were made in November, 1917. In order to expedite production and to establish inspection on a firm basis both Army and Navy Inspectors were kept in close touch with the factory operations. They inspected large quantities of glass in process of manufacture before it had reached the stage for final inspection and acceptance. Although this practice was different from the established Government procedure to inspect only the finished articles specified in the contracts, it was found in every instance to be beneficial both to manufacturer and to inspector because it led to a clear understanding of the significance of the specifications and of the steps essential to meet them satisfactorily.

In each Government contract for optical glass the tolerance limits for refractive index and optical constringence were made as large as possible, about $+0.002$ in refractive

index, n_D, for each type of glass. But in the early months of the war good melting pots were not available and it was difficult for the manufacturer to hold the melts of a given type even to these limits. The difficulty was overcome, in part at least, by shipping to a given manufacturer glass so selected from the different melts that the range of refractive indices was within certain tolerance limits. Unfortunately this plan was not followed consistently because of lack of proper care at the Army and Navy distributing centers and, as a result, many manufacturers did receive shipments containing glass with much wider variations in refractive index than should have occurred; much time was thereby needlessly lost in changing and adapting tools to meet the relatively large fluctuations in refractive index. This situation arose because of a lack of appreciation on the part of certain Army and Navy officials of the optical glass requirements. The same lack of optical sense led one zealous officer to enter a glass plant before adequate inspection had been installed, and to order sent to a manufacturer who was much in need of glass about a ton of glass which had not been adequately inspected. The manufacturer in turn failed to inspect the plates before putting them into work, with the final result that several thousand, otherwise high grade prisms, had to be rejected because of faulty glass. This case is cited because it shows that the officer's action, commendable as it may have been in some respects, led only to disaster and waste of effort, because the material with which he had to deal was optical glass and not simply glass or copper or zinc for which his order might have been justified. The war-time experience proved the need and value of trained personnel to organize and co-ordinate scientific and technical work; it proved the futility, as in the above case, of assigning any man or officer to a technical task for which he has no background of experience. It demonstrated the necessity of centralizing among a chosen, competent few the task of handling the many factors which arise in connection with a technical matter such as optical glass and optical instruments. The records show that this plan was finally adopted with the result that in the latter part of 1918 the optical glass situation was well co-ordinated and well in hand.

Too strong emphasis cannot be placed on the need for properly trained personnel to handle technical problems of this nature. In the last analysis personnel is the prime factor involved, and the nation which, during peace times, properly organizes and co-ordinates its scientific and technical forces so that they can be called upon in an emergency, has an immense advantage over a nation whose Army and Navy are out of touch with these forces. Proper co-operation between the civilian and military elements is essential in peace-time if there is to be an effective working together during war-times. Failure to appreciate this fact before the war cost this country much during the war and after. In highly technical lines, especially those which have to do with engineering and scientific problems where special skill and experience are necessary, civilian experts are commonly in close touch with the details and are in a position to give good advice and aid. One of the chief difficulties encountered in the optical instrument situation during the war was the remedying of errors made by officials and officers who had been detailed to the job but who lacked knowledge of the problems and were in many instances a hindrance rather than a help.

This situation can be met only by a realization of the need for the adequate training of a selected few men in the Army along optical lines, not simply as users of optical instruments, such as range-finder and field-battery observers, but also as inspectors of optical instruments. It is equally essential that a certain number of civilians who are well grounded in optical theory be instructed from time to time in ordnance optical instruments, their field use, care, and inspection, so that in case of war these men may be ready as a nucleus to bear the burden of inspection and manufacturing supervision and to train others rapidly to become qualified inspectors. If a peace-time policy of this sort were followed, civilian interest in these matters would be maintained, with the result that in the event of war a potential organization of high efficiency would be available. War-time experience proved that men with a good working knowledge of optics soon became proficient inspectors and officers competent to handle optical matters; but that men,



Pouring molten glass on flat iron table to be rolled into large thin sheets.

without this background of optical training, assigned as officers to optical-instrument problems, proved incompetent and did actually more harm than good, stopping production here because of the arbitrary setting of tolerance standards which could not be met, and expediting production there which eventually proved to be useless because of the lack of proper tolerances and competent supervision. In retrospect these occurrences may be passed over with equanimity, but during the war they meant constant trouble and discouragement, both for the manufacturer and for the field forces; nor did it increase the respect of the manufacturer to find the inspector ignorant of the essentials of the technical subject to which he had been assigned and hence incompetent to deal intelligently and constructively with it. On the other hand, it was an inspiration to witness the zeal and ability with which a certain few officers and civilians of thorough grounding attacked and solved the problems; and particularly to see manufacturers lay aside other work in order to undertake the making of the military optical instruments needed by the field forces. It was this spirit of willingness to tackle a job and see it through that carried the manufacturing program through to a successful end in spite of the lack of preparation and adequate training; but the cost of so doing and of learning by experience was exceedingly high.

Early in 1918 the requests for optical glass became so insistent from so many manufacturers that in March, 1918, a special section, called the Military Optical Glass and Instrument Section, was created by the War Industries Board to handle the situation. It soon became necessary, because

of the very large demands of the Army and Navy for optical instruments, for this section to take complete charge of the industry and, by a system of permissions, to supervise the entire output of all manufacturers of optical glass and of optical instruments. Commercial orders were restricted to absolute necessities; requests for priority were passed upon. The optical glass, as produced, was controlled and distributed by this section to the several Government departments and to manufacturers having direct Government orders. It was through this absolute control of the optical-glass output that the entire optical industry could be so easily and effectively controlled. Responsibility for the manufacture of the required quantities of optical glass was placed with the Director of the Geophysical Laboratory.

Statistical reports were prepared weekly at the different plants showing the amounts of different types of optical glass ready for final inspection.

The requirements of the Army and Navy for optical instruments were carefully tabulated and their relative needs for optical glass thereby ascertained. Allocations of optical glass were made with reference to these needs. This mode of operation of the section proved successful in every respect. The manufacturers, realizing the necessity for centralized control, entered into the plan wholeheartedly, accepted the rulings and requests of the section and observed them conscientiously. The chief function of the War Industries Board was not to restrict industry, but to direct it effectively to work on munitions.

Both the Army and Navy placed orders for optical instruments during the early months of the war, at a time before intimate contact with the armies in Europe had been established. With one or two exceptions these orders were placed with optical-instrument makers of established reputation who were in a position to produce the articles ordered provided the necessary optical glass were made available. The orders, moreover, were for certain standard instruments, such as range-finders, aiming circles, battery commander telescopes, naval gun sights, field glasses, camera lenses, etc. These orders effectively covered the entire manufacturing capacity in this country for 1917 and part of 1918. The policy of placing orders with firms of recognized standing and, in case an inexperienced firm solicited a contract, of awarding a part only of the required number to the new firm and the remainder to an old firm, proved to be a wise policy. The old firms proceeded to fulfill the contracts, and in time delivered the instruments; many of the new firms required assistance, and in this connection the War Industries Board aided materially.

By the end of 1917 requests for many new types of instruments which the European armies had found useful in the field, began to flow in from the American Expeditionary Forces. The optical industry was then confronted with the situation that the available manufacturing capacity was practically bespoken for some months to come. The result was an energetic appeal to each manufacturer from the several departments of the Army and Navy to accept more orders, each department considering only its own needs. Careful search was made for manufacturers who might be persuaded to undertake optical work. By February, 1918, the general confusion which existed because of the many diverse, non-co-ordinated agencies at work led to the realization of the need for centralized control, and in a short time furnished additional reasons for the formation of the Military Optical Glass and Instrument Section on the War Industries Board.

In April, 1918, an Army Commodity Committee on Optical Glass and Optical Instruments was formed, with the Army Representative on the Optical Section of the War Industries Board as Chairman, for the purpose of co-ordinating the Army needs for optical instruments. This committee functioned under the Director of Purchases and Supplies. It held monthly meetings and served to bring together the Army officers directly concerned with optical munitions. One of the results of the efforts of the Director of Purchases and Supplies was the consolidation, in the Ordnance Department, of the procurement of all optical munitions for the Army with the exception of a few special instruments. Strenuous objection to the consolidation was made at first by certain Army departments on the plea that special knowledge was required to purchase the optical instruments required by them; but the results of this consolidation proved that the fears thus expressed were groundless, partly because the Ordnance Department officer directly responsible for the procurement of optical munitions was thoroughly trained to the task and experienced in optical matters.

From April to August, 1918, an earnest effort was made by the War Industries Board, the Army, and the Navy to interest manufacturers who might undertake the production of optical munitions. The result was that many firms who had never done work of this kind patriotically accepted contracts for instruments or optical or mechanical parts and at the time of the signing of the Armistice were producing satisfactorily. In general, the policy was followed to let contracts for instruments of high precision to experienced firms and to reserve the simple types of instruments for the less experienced makers.

As a further incentive to expedite production, the Ordnance Department established a training school for lens and prism operatives at Rochester, N. Y. It was felt that, were the opportunity offered, many young women might engage to do work of this kind during the war. At the Rochester school a number of operatives were thus trained; but the experience was not altogether satisfactory, chiefly because of a lack of real interest and support on the part of the large optical manufacturers in Rochester. A school of this nature, to be successful, requires the enthusiasm and interest of good teachers, and these evidently could not be spared by the larger manufacturers. A second, more successful school, was established at Pasadena, Calif., for the training of expert grinders and polishers for precision optics, chiefly roof-angle prisms. This school was operated in connection with the optical shop of the Mt. Wilson Observatory, of the Carnegie Institution of Washington.

The optical industry during the war proved equal to the emergency and, by the time the Armistice was signed, was rapidly approaching the peak value of deliveries. Production and deliveries were proceeding on an immense scale. By this time the industry had been well organized and co-ordinated. New additions had been made to old factories, new factories had been erected and a manufacturing capacity for optical instruments adequate to supply the needs of both the Army and Navy for 1919 was available. This condition had been practically attained by September, 1918. Many of the instruments in course of manufacture were, however, direct copies of European instruments and manufacturers complained because the designs had not been made with reference to American methods of quantity production. In many instruments a great saving both in time and expense could have been effected by appropriate changes in design without affecting in the least the field performance of the instrument; but to accomplish this properly, time and much consultation would have been re-

quired; and, early in the war it was decided best, under the circumstances, to go ahead with production of usable designs, even if they were direct copies of European instruments, and thus to insure the desired output. As soon as adequate production had been established, steps could be and actually were taken to improve and to standardize the designs of many of the instruments.

With the signing of the Armistice the need for further production ceased. Many contracts were canceled outright and appropriate settlements were made; others were canceled in part, and still others were allowed to continue to completion. Manufacturers who had engaged in optical work only as a patriotic duty returned to their normal peace-time activities. The optical-instrument manufacturers themselves were soon deluged with commercial orders, because of the release of all restrictions and control of the industry by the War Industries Board on Nov. 16, 1918. Thus the transition from war-time to peace-time activities was begun.

After the Civil War there was no corresponding adjustment of the optical industry. The total value of orders for optical apparatus during the Civil War was almost negligible. During the recent war the total value of Army and Navy orders for optical munitions was over $65,000,000.00, of which about $50,000,000.00 was for the Army. What it may be in another war a century or even some decades hence no one can tell; but, if the lessons of the recent war have not been entirely forgotten, this country will be in a better position to produce the necessary optical munitions than it was in April, 1917.

The records show that during the recent war we received no assistance, either direct or indirect, from other countries in the solution of the problems of optical-glass manufacture. The details of optical-glass manufacture were held secret in all European countries and were not to be divulged even under the stress of war-time needs. Fortunately it proved possible for us to make good optical glass without the knowledge of these secrets, which, in point of fact, may prove to be double-edged and serve to impede progress and to be an actual hindrance rather than an aid to a manufacturer if he holds them in too high esteem. The results of our work are being published freely, because we feel that in the manufacture of optical glass secrets serve no useful purpose.

Although large quantities of optical glass are not needed, optical glass is an essential part of all instruments of observation. The optical-glass industry is, therefore, a singularly important key-industry, the control of which means control of a whole series of industries and of research and technical laboratories and institutions. It was probably for this reason that we were unable to secure any information regarding its manufacture from other countries.

It is only fair and just to admit that in addition to the many other elements essential for the production of optical glass in this country we were favored by good fortune and made the best of it. If a future emergency should arise, it can hardly be expected that a laboratory of similar experience will be available or that the manufacturers will have builded so wisely beforehand. It is, therefore, a wise policy for the Government to encourage the manufacture of optical glass in this country by placing orders, during peace times, for optical glass with the manufacturers, thereby maintaining the essentials of the organization and, at the same time, building up a reserve stock of good glass against a possible emergency. This policy is being followed by certain other countries. In the case of optical instruments similar arguments are valid; but the fact that new instruments are being devised constantly makes it inadvisable to store large stocks of these instruments. The maintenance of optical repair and manufacturing plants by the Army and Navy is a wise provision, because these function primarily as training schools for personnel against the hour of need.

In view of the highly technical nature of optical instruments in design, production, and repair it is desirable that a single optical plant with competent personnel should serve the entire Army. It is not feasible, and would be unwise, for the different departments of the Army each to maintain separate optical shops, or even separate sections for the design, only, of optical instruments. The argument has been advanced that in any given branch of the service only the members of that service have adequate knowledge of the field conditions under which it operates and that, therefore, they alone are competent to design the apparatus needed. This is no doubt true for much of the material required,

Breaking off pot walls after first melting

but, in the case of optical instruments, special conditions exist which render this plan unworkable. Optical engineers of experience are scarce and are unwilling to spend their entire time on the few problems offered by any single branch of the service. The particular problems, moreover, which any Army department considers peculiar to itself have much in common with those of other departments; and for each department to maintain separate sections for the design of optical instruments would mean serious and inefficient duplication of work with consequent waste of time and of public money.

The fact that both in war time and in peace time the Ordnance Department is responsible for the bulk of the Army optical work and has built up a satisfactory optical shop at Frankfort Arsenal with competent personnel indicates that all Army optical work should be done there; also that Frankford Arsenal should be made responsible for the design and production of all experimental optical instruments suggested to meet any new conditions which may arise. The special knowledge of the conditions under which the proposed new instrument is to function can be given by officers or civilians of the special branch of the service which is to use the instrument, but the design of the instrument, to satisfy these conditions and to be at the same time a manufacturing possibility, should be made at Frankford Arsenal as the logical optical organization within the Army. It is imperative that the Army and the Navy each maintain an optical plant not only for the design and test, production, and repair of military instruments, but also for the training of personnel along these lines. It is for this reason especially that no other department of the Government can function satisfactorily for the Army and Navy in this respect, and that the Army and Navy optical shops cannot well be consolidated into one large shop.

The Aberdeen Proving Ground

By

H. W. SCHULL

Member A. O. A.

THE Aberdeen Proving Ground, although a development of the World War, is a permanent Army Post. It is the place where the Ordnance Department of the Army conducts its test in connection with the development, proof and acceptance of all kinds of ordnance materiel, including machine guns, field cannon, anti-aircraft cannon, railway cannon, tractor-drawn and tractor mounted cannon, tanks, ammunition, bomb, and bomb sights for aircraft use, etc. Nowhere in the United States can such a variety of ordnance be seen in action, a fact which has resulted in its being chosen by the Army Ordnance Association as the place for holding its last two annual meetings.

For many years prior to the entrance of the United States into the World War, and subsequent to that time, until about January 1, 1918, practically all experimental and proof work in connection with the development and acceptance of ammunition and cannon for the army was performed at the Ordnance Proving Ground at Sandy Hook, N. J.

Very early in the war, however, it became evident that the facilities and space existing at the Sandy Hook Proving Ground would be altogether inadequate and that a vastly greater land area would be absolutely necessary to carry out simultaneously and without interruption the many activities in connection with proof and development work under the great ordnance manufacturing program. In considering the selection of the site for the new proving ground, many places were investigated and a very thorough study of the subject was made before the present location was chosen.

A matter of prime importance in the selection of the proving-ground site, especially during the war, was the question of its accessibility from the principal manufacturing and industrial centers of the country. Other questions of equal or almost equal importance were those of obtaining a site where the weather conditions were favorable throughout the year, and an area large enough and sufficiently remote to permit work to go on uninterruptedly and without undue danger or disturbance to the adjacent communities.

The Aberdeen Proving Ground site seemed to fulfill most of these conditions better than any of the other localities that were considered available at the time. It is situated on the northwest shore of the Chesapeake Bay, about four miles from the town of Aberdeen, Md., which is nearly midway between Baltimore and Philadelphia. The transportation facilities are especially good, inasmuch as the main line of the Pennsylvania Railway and Baltimore and Ohio Railway pass through the town of Aberdeen, while the Chesapeake Bay affords opportunity to ship by water to and from all points.

The Aberdeen Proving Ground contains about 35,000 acres, and has a maximum length of about fifteen miles and a maximum width of over four miles. The site became the property of the United States in the early part of October, 1917. It was at that time almost entirely given over to farming, truck gardening and canning industries, and occupied by a considerable number of land owners and small tenants. All of these people, representing several small villages, had to be dispossessed, and vacate their homes by a date set in the latter part of December, 1917. The construction of the plant began immediately after the property was acquired.

The first shot at the Aberdeen Proving Ground was fired on the second day of January, 1918. During that month about 5,000 rounds were fired, and this number increased steadily each month until, during the month of August, 1918, a total of 71,000 rounds were fired. These firings were all made in proof, acceptance or development of ordnance materiel, and the results had all to be reduced to writing, recorded and forwarded to the various agencies in Washington and elsewhere for use in design work and as the basis for the acceptance of materiel by the Ordnance Department.

To carry out this work expeditiously necessitated the building up of a great industrial organization. On November 30, 1917, the personnel at the Aberdeen Proving Ground consisted of ten commissioned officers, thirty-five enlisted men and twenty-three civilian employees. By September 30, 1918, this personnel had increased to two hundred and seventy-two commissioned officers, 4,028 enlisted men and 1,200 civilian employees. In addition to the above, the contractors were employing at the proving ground about 3,000 men on the construction of the plant.

The history of the growth of the Aberdeen Proving Ground is similar in most respects to that of many other great projects in this country during the war. It differed materially in one important aspect, however, in that the proof work had to go on and grow simultaneously with the increase of the manufacturing program and with the building of the plant.

By the time the Armistice was signed a total of about 300 buildings, of a temporary nature, for the housing of the military and civilian personnel, including quarters, barracks, mess halls and hospital, had been constructed. Like all buildings of similar nature erected at plants and cantonments during the war, these buildings were of a more or less flimsy type, and are being torn down as rapidly as they can be spared. They should be replaced by properly constructed buildings of sufficient capacity to house the permanent garrison as soon as appropriations become available.

In addition to the temporary buildings, twenty-six buildings of a permanent nature were constructed, including a well-equipped modern machine shop, a carpenter's shop, a railway station, a number of storehouses, a power plant, water towers, etc., also work of a permanent nature represented by eleven miles of concrete road, seventeen miles of

water pipe, fifteen miles of sewer pipe, fifteen miles of electric wiring, thirty-two miles of railway track, and many other facilities needed to run a plant of this kind.

For the purpose of transporting men and material, eight locomotives, seventeen locomotive cranes, thirty-four railway cars and eight passenger coaches were kept and used continually at the proving ground during the war. This amount of equipment has, of course, since been greatly reduced and is now only sufficient to meet the needs of peacetime conditions.

The total cost of the Aberdeen Proving Ground to date, exclusive of the cost of operation, has been about $16,000,000. Of this amount about $3,550,000 covers the purchase of land and the remainder the cost of construction of the proving ground, including equipment.

The original appropriation for the Aberdeen Proving Ground was $7,000,000, but as construction proceeded and the war program increased, one project after another was added to the original plans so as to keep pace with the increase in the army. On the signing of the Armistice, work on most of the proving ground projects, uncompleted at that time, was stopped or slowed down, and only those essential to the operation of the proving ground in proof and development on a peace-time basis have since been carried to completion.

Mobile Artillery Firing Range

With the exception of the land at the north end of the reservation, occupied by barracks and quarters for the garrison, administration building, storehouses, shops, railway station, train yards, etc., nearly the entire area is available for firing ranges, recovery fields, bombing fields, etc., and the facilities and equipment are very well adapted for the various classes of work that arise in the devlopment and proof of ordnance materiel.

From the gun positions along the main firing front, which is equipped with all apparatus necessary for making special tests of ammunition and mobile artillery up to 9.2″ in caliber, a land range of from 25,000 to 30,000 yards may be obtained. From the railway and seacoast artillery firing fronts a range over land of from twenty to thirty thousand yards, and over water up to sixty thousand yards, is obtainable. For observation of fire over the water, there are twelve range towers at intervals along the eastern shore of the bay for a distance of twenty-five miles from this firing front.

The two firing positions referred to in the preceding paragraph afford facilities for testing all calibers and kinds of artillery, including field artillery, railway artillery and seacoast artillery. Apparatus is now being installed to enable necessary special tests to be made of tanks, tractors and self-propelled mounts. This apparatus will include means for making complete dynamometer tests of gas engines and demonstrations with the vehicles assembled and disassembled to simulate road conditions and to ascertain whether or not the specifications under which procured are fulfilled.

There is also under construction at this time a new firing range for testing small arms and machine guns and the ammunition therefor. Details of this range are described in the article by Maj. L. O. Wright in this issue.

For the purpose of assisting the Ordnance Department in conducting tests of bombs, bomb sights and other aircraft armament, there are stationed at the Aberdeen Proving Ground a Heavy Bombardment Squadron and a Balloon Company of the Air Service. The personnel of the Heavy Bombardment Squadron assists the Ordnance Department in the collection of data used in the tests of bomb sights and makes such tests as may be required of bombs. The Balloon Company also tests drop bombs, and for this purpose there have been provided bomb-testing facilities, such as a special building of oak lumber to be used as a target and an acre of concrete three feet thick to be used as a target in certain special bombdropping tests.

Railway Artillery Firing Range

The operation and maintenance of the Aberdeen Proving Ground is a function of the Technical Staff of the Ordnance Department, and all proof and development work at this place is carried out under instructions received from the Technical Staff, generally in the form of ordnance programs. These programs describe in detail the work to be performed by the personnel of the proving ground. Inasmuch as the results of the tests performed determine whether or not new designs are satisfactory or whether or not materiel procured by the Ordnance Department by contract fulfills properly the specifications, the work must be performed at the proving ground with great care.

To carry out this work satisfactorily necessitates having at the Aberdeen Proving Ground a military establishment and a complete industrial organization, including personnel capable of performing the highly technical and engineering work involved in testing and reporting intelligently on the tests of the various classes of ordnance materiel. The personnel of the Aberdeen Proving Ground at present consists of 32 commissioned officers, including the Commanding Officer, 363 enlisted men and 435 civilian employees.

The military establishment at the Aberdeen Proving

Ground, insofar as pertains to its general organization, is similar to that obtaining at other army posts, and consists of the Commanding Officer, the Adjutant, the Quartermaster and other administrative and executive officers, together with the enlisted personnel. The enlisted personnel consists of the following organizations:

Ordnance Detachment.
Ordnance School of Application Detachment.
Aircraft Armament Detachment.
Fifth Heavy Mobile Ordnance Repair Shop.
Flight "B," 258th H. B. Squadron.
Eighteenth Balloon Company.
Medical Corps Detachment.
Meteorological Detachment, 4th Ser. Co., Signal Corps.

The industrial organization is adapted to the particular needs of the proving ground, and insofar as pertains to proof work, operates under seven main sections or divisions as follows:

The Instrument Section, having charge of velocity measuring instruments, star-gauge instruments, etc.

The Range and Ballistic Section, which has charge of tests and experiments connected with firings for range and experiments with types of projectiles.

The Mobile Artillery Section, which has charge of proof and acceptance tests of mobile artillery.

The Tank and Tractor Section, which has charge of proof and acceptance tests of tanks, tractors and self-propelled mounts.

The Railway and Seacoast Section, which has charge of all proof work connected with railway artillery, seacoast artillery and ammunition for the same.

The Aircraft Armament Section, which has charge of all work connected with proof and development of bombs and bomb sights for aircraft armament.

The Small Arms and Machine Gun Section, which has charge of the test of small arms and machine guns and ammunition therefor.

By means of this organization the proving ground is able to handle efficiently the tests of the various classes of ordnance materiel as directed by the Technical Staff.

Aberdeen Small Arms Firing Range

By

LEE O. WRIGHT

Member A. O. A

ONE of the most important developments of the World War was the extensive use of machine-gun fire at ranges never before thought possible.

Our small-arms ammunition was designed to give extreme accuracy and a very flat trajectory up to 1,000 yards. Beyond that our range tables were determined theoretically. When an attempt was made to use the ammunition for long range machine-gun fire, it was discovered that theory and practice did not agree—the tables were dangerously inaccurate at ranges beyond 1,500 yards.

As no facilities for testing this type of ammunition at long ranges existed at any government proving ground or arsenal, a small-arms proving ground was established in France and another in Florida, private property being leased for the purpose.

As a result of these firings, range data were determined and have been used as provisional tables of fire. A study of the comparative trajectories of different types of foreign small-arms bullets shows that a number of them have greater range than our caliber .30 Model 1906 cartridge. Experiments have been under way for some time to develop a caliber .30 bullet with much greater range than our present type, and we are also developing a .50 caliber machine gun and ammunition with which it is hoped a range of at least 6,000 yards may be obtained.

For the complete testing of these types of ammunition and the testing of special ammunition—tracer, incendiary, etc.—a small-arms range is being constructed at the Aberdeen Proving Ground, Md.

This range consists of a pool of water 1,000 yards long by several hundred yards wide, with a narrow-gauge track running back for a distance of about 6,200 yards; the pool is formed by a bend in Romney Creek and is almost ideal for the purpose desired; the average tide is only about 1½ feet and woods surround it on almost all sides, cutting off the wind.

Three rows of range stakes are placed in the pool, 20 yards apart, dividing an area 1,000 yards by 40 yards into 20-yard squares, the 100-yard stakes being marked with the range, the intermediate numbers being painted distinctive colors.

Seventy-five yards from the center line of stakes are located five 40-foot observation towers one hundred yards apart, the center tower being opposite the 500-yard stake. The observation stations on top of the towers are protected with .6″ armor plate on top and .85″ armor plate on the side toward the firing point.

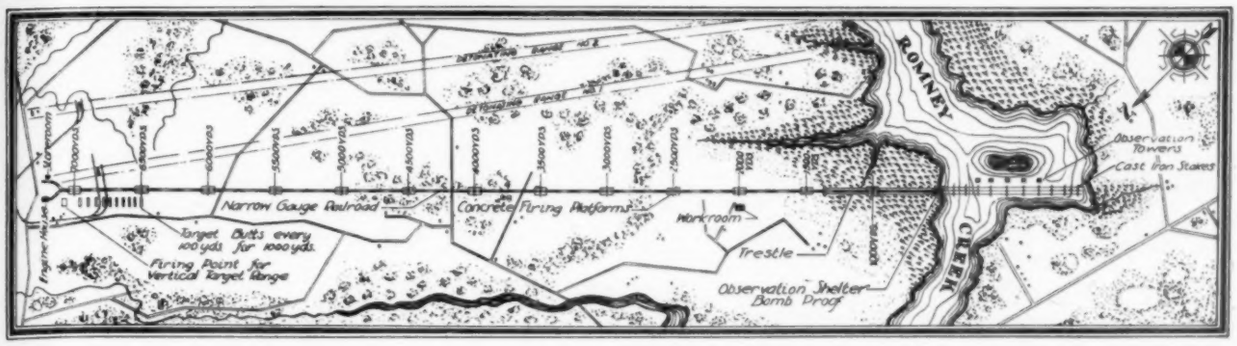
At the near edge of the pool, in prolongation of the center line of stakes, is an observation station for determining lateral deviation. A narrow-gauge track in line with the center line of stakes runs back to Michaelsville, where it connects with the standard gauge post track. Every 500 yards along this track is a firing platform of concrete 10 by 12 feet. In exact alignment with the center row of stakes a brass datum point is located, with its height above mean low water recorded.

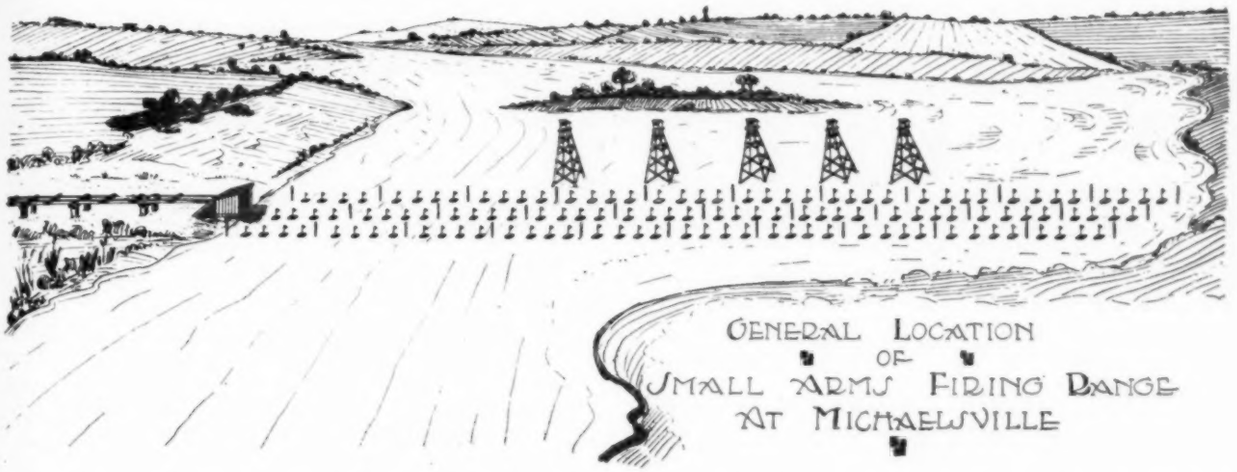
As most of the long-range firings will be conducted at ranges from 1,500 to 3,000 yards, a 20 by 30 foot frame building has been erected 1,500 yards from the pool, to serve as a workroom and storeroom. A general storeroom and engine house is located at Michaelsville at the end of the track.

There is also to be constructed at Michaelsville, alongside the track, a series of target butts every 100 yards, up to 1,000 yards. These butts are arranged in line with the tops of the butts of equal height.

Telephones connect the towers, the lateral deviation station and the workroom and storeroom. Arrangements are made to plug in on this line at each of the 500-yard firing platforms. A separate telephone system connects the vertical target butts with their firing platform.

On this vertical target range accuracy and trajectory firings up to 1,000 yards will be conducted. As arranged, the intermediate height of trajectory at any point on this range can be easily determined by running up the desired target and determining the height of the bullet hole above





the line joining the gun and the center of impact at 1,000 yards, or any other desired range. Firings for ranges beyond 1,000 yards will be done on the water.

For this long-range firing, the machine rest, machine tripod, or other device for holding the gun, will be mounted on a flat car. The car will be run over one of the 500-yard firing platforms and the exact height of the center of the gun above the water will be determined from the datum marks.

At ranges up to 2,500 yards the aiming point will be a vertical pole on the observation tower at the near end of the pool. For ranges beyond that it will be necessary to place an aiming point over the datum point from one of the firing platforms toward the water.

Observations for range will be made from the towers. As the impact area is divided into 20-yard squares, with each post distinctly marked with the range, the point of impact can be determined within a very few yards without any instruments. For extremely accurate work, or where it is desired to obtain the exact point of fall for each bullet from machine-gun bursts, motion-picture cameras will be employed. By this method it is expected that each and every shot can be located and the exact point of fall can be determined at leisure. Ordinarily the deviation caused by wind, drift, etc., and the lateral dispersion of the machine-gun bursts can be determined by an observer with instruments in the station at the end of the pool.

Time of flight ordinarily will be determined by observers with stop-watches in the towers, who will be connected by telephone with the firing point.

An investigation is being made as to the possibility of using microphones submerged in the water and connected to suitable recording instruments. If this is perfected, the personal element in making these important observations will be eliminated.

For true range firings, it is necessary to measure the angle of departure, and not the angle of elevation, in order to eliminate the variable "jump" of the piece on discharge. This will be accomplished by firing through thin paper screens suitably mounted on another car and placed about 100 feet from the gun. The line between the hole, the horizontal and the center of the gun and the center of the screen is the quadrant angle of departure.

The same arrangement, suitably modified, will be employed in determining the angle of departure when firing on the vertical target range.

The velocity of the ammunition being tested will be determined before each day's firing, as it has been found that the velocity is liable to vary with storage.

For the general plan of this range, the department is indebted to Major Glenn P. Wilhelm, who has conducted extensive range firings* during the past two years at Miami, Florida, and Daytona, Florida.

For many years the Ordnance Department has had a proving ground for the testing of artillery ammunition; small arms ammunition being tested at the manufacturing arsenal, where a 600-yard range was available. The establishment of this range at Aberdeen is a recognition of the importance of the weapons of the Infantry, as brought out in the world war. Until recently the Ordnance Department devoted a much greater portion of its time to the development of artillery weapons and ammunition than it did to Infantry weapons and ammunition. It should be remembered, however, that prior to 1914, the need for

*[Now being described in current numbers of ARMY ORDNANCE.—ED.]

(Continue on Page 281)

Flexural Buckling

By

ALBERT E. GUY
Member A. O. A.

[A problem of marine engine design encountered some twenty-five years ago, and in which the question of least weight was of prime importance, led the author of this article into a merry chase after theoretical data for its solution. This data he did not find because it did not exist; then he resorted to experimentation and soon discovered the new laws of Flexural Buckling. The results of his tests were published in part in 1902. Recently several questions of design of ordnance material were brought to the author's attention, and he found that their solution depended to a large extent upon the application of the Flexural Buckling formulæ. However, it was necessary to extend and verify these latter in order to meet some particularities of these questions. Permission was given for conducting the required tests and the Ordnance Department, realizing that the resulting knowledge is likely to prove of value in general engineering work, has gladly acquiesced in the publication of this new development.

The field opened by the author is of very large extent, and only a few of the usual cases have been investigated. An immense amount of work remains to be done through experimentation, in seeking to establish the mathematical theory of Flexural Buckling. Anyone acquainted with the theory of columns as treated by Euler and other celebrated mathematicians will realize the magnitude of this task. For this reason, the author urgently requests the co-operation of elasticians and engineering colleges in this important work.—ED.]

COLUMNS, struts, and in general, all structural compression members, are designed to withstand not only the compressive stresses applied axially but also the incident tendency to give way laterally by bending, or more properly, by buckling. When the case is simple and well defined, for instance that of a strut of uniform section, the area of that section is so chosen that the stress per unit of area is well within the limits sanctioned by practice; and in addition, the least moment of inertia of that section must be such as to insure the safe elastic stability of the strut.

That beams subjected only to simple bending efforts may buckle precisely as axially loaded struts do was shown for the first time about eighteen years ago, when the results of some four thousand tests were published in the columns of the *American Machinist*. A number of incidents which came recently to his attention, such as the giving way of the jib of a locomotive crane, causing the death of two men, the deformation of certain parts of ordnance materials, and some problems involving combinations of stresses, prompted the writer to give additional publicity to the subject, thus emphasizing certain ponts of vital importance and providing handy tables for the use of the designer.

As it was necessary to verify the effects of some combinations of stresses, the writer was duly authorized to proceed, and a very simple apparatus was quickly rigged in the writer's office, and that furnished an excellent occasion for demonstrating the fundamental laws before officers of several Ordnance Sections.

The Four Principal Laws

These laws are stated here as applying exclusively to cantilever beams of uniform rectangular section; it will be shown, however, that they apply equally well to *uniform* sections of any shape, and to beams held or supported in various manners.

Three axes are to be considered:

(1) The longitudinal axis of the beam; assumed to be originally straight;

(2) The greatest, or major axis of the cross section, in the direction of which the load is applied *and maintained;* this axis is always understood as in the same plane with the longitudinal axis; hence, these two axes and the direction of the load should remain in the same plane until the ultimate load increment brings about the failure of the beam through lateral buckling;

(3) The smallest, or minor axis of the cross section, always perpendicular to the "axes-load" plane.

First Law. A horizontal beam held fixedly at one end and loaded at the other will buckle when the load reaches a certain value, and with the same load acting always vertically the beam will buckle for any given angular position of its longitudinal axis, from the horizontal to the vertical; that is, through a range of 90 degrees.

Second Law. The load causing the buckling of a beam through flexure is inversely proportional to the square of the length upon which it acts directly.

Third Law. The load is directly proportional to the cube of the thickness and to the height of the section, or generally, directly proportional to the moment of inertia of the cross section of the beam, taken in reference to an axis (the major) passing through the center of gravity of the section, in the plane of action of the load.

Fourth Law. The total effect of one or several forces is equal to the algebraic sum of their individual effects.

Easy Experimental Proof of the First Law

The most gratifying thing about this whole subject is that the laws may be proved by simple means. The beam specimens may be of clear white pine, about 30 inches long and of uniform rectangular cross section. The specimen should, of course, be straight. The cross sections may vary between 1 inch by 3/16 inch to 2½ inches by ⅜ inch. Any other convenient kind of wood may do as well, and any other preferred sizes may be used. The main purpose in selecting bars of relatively diminutive size is to facilitate both the manipulations and the observation of the phenomena. If such laws exist they should be capable of ready proof. It may be again objected that even if the laws are clearly proven by means of small specimens they may fail to apply in practical applications where compression members and beams become relatively to these of enormous sizes. The answer is that the material of the small bar is always more uniform, could be called more perfect, than that of a large beam. A single glance will convince anyone. Therefore the small bar may be considered as a simple case whereas the large beam would be a complex one. Objection may also be made against the use of wood instead of metal. Wood is preferable to metal because the loads required are smaller, cheaper and the adjustments can be secured with a lesser degree of precision. However, let it be clearly understood that the writer has verified the laws by testing steel bars; the results have been the same as with wooden bars, with the exception that the loads were increased in the proportion to the modulus of elasticity of the material. Thus, the buckling load for a given wooden beam being 17 pounds,

for example, a steel bar of the same size would require about 391 pounds, since the modulii are, respectively, about 1,300,000 and 30,000,000 and their ratio 1 to 23, very nearly.

To test the first law all the refined material required is a flat stick, say one plastering lath. However, select it straight and free of too obvious defects. Squeeze it at one end between two pieces of hard wood in a swiveling vise. Hold it at first in the horizontal position and load it at the free end as shown at A in Fig. 1. Increase the load gradually until the beam shows sluggishness in vibrating laterally; then keep on applying smaller load increments and finally a point will be reached at which no further increase will be possible. The beam will then fall, or warp, to one side and would collapse entirely if not prevented by a slight pressure from the fingers applied at the loading point. Now remove the load partially, shift the beam to *any angular position B*, and apply again, but gradually, the full load. The beam will collapse under precisely the same load as at A. Shift the angular position of the beam, after partial unloading, to the vertical direction CO, and again the same total load will produce the buckling.

This test may be repeated with different lengths of the same bar, but, for each length, the load will of course be different. It will be found that buckling will occur at any angular position of the beam on the quadrant.

For the complete success of this test three things are essential: (*a*) The load must always act in the vertical direction; (*b*) the load must be so applied at the end of the beam as to leave to the latter complete freedom to bend, and to warp laterally when the limit is reached; (*c*) the direction of the load must lie in the plane passing through the major axis and the longitudinal axis.

At the beginning of previous experiments the suspension members of the load were defectuously arranged, and it was found that they actually restrained to some extent the free warping of the loaded end. The result was that the recorded loads followed broadly the general law, but with some irregularities which could not very well be accepted as matters of course. The trouble was eradicated entirely by the use of the suspension device shown in Fig. 2. This device hardly needs description. It is composed of a small steel rod, notched at each end, attached firmly to the beam by means of nuts and washers, and so disposed that its axis coincides with the minor axis of the section and that the notches are equidistant from the major axis; two steel strips fit on knife edges in the notches and reach downwards to another notched beam, at the middle of which a knife-edged strip rests while supporting the loading platform. The whole forms a suspension parallelogram, freely deformable to suit the angular displacements of the section while insuring the direction of the load to pass through the intersection of the minor and major axes.

A little difficulty may be experienced when nearing the limit load; if the latter's direction is not kept precisely in the axial plane, the beam being considerably bent in ordinary flexure will develop a marked tendency to warp through induced twisting, which the operator is at first apt to mistake for buckling; however, with a little experience and care, the plane of action may be re-established, and with slight additional loading the true limit will be obtained.

The Second Law

The beams being held horizontally in the vise, with the greatest permissible length between the points of support and of loading, the buckling load is determined in the manner afore-described. The length is then reduced by a predetermined amount and the new buckling load obtained. This process is continued until the length becomes so short that the beam may break by simple bending. As a matter of precaution it is well to ascertain by a few tests what this limit is for beams of given cross sections, and then to remain well within the limit.

It will now be found that for each length tested *the product of the recorded load by the square of that length*

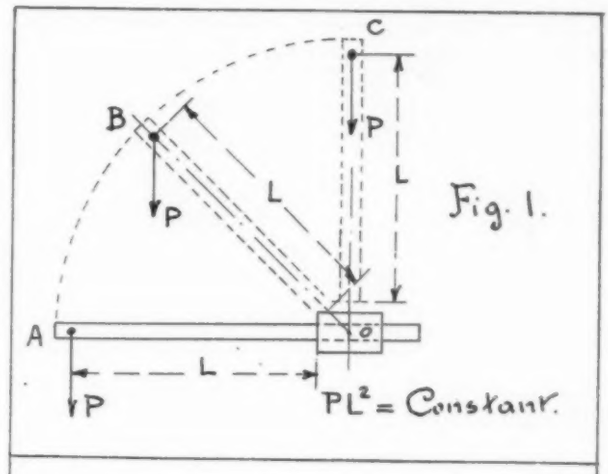


Fig. 1.

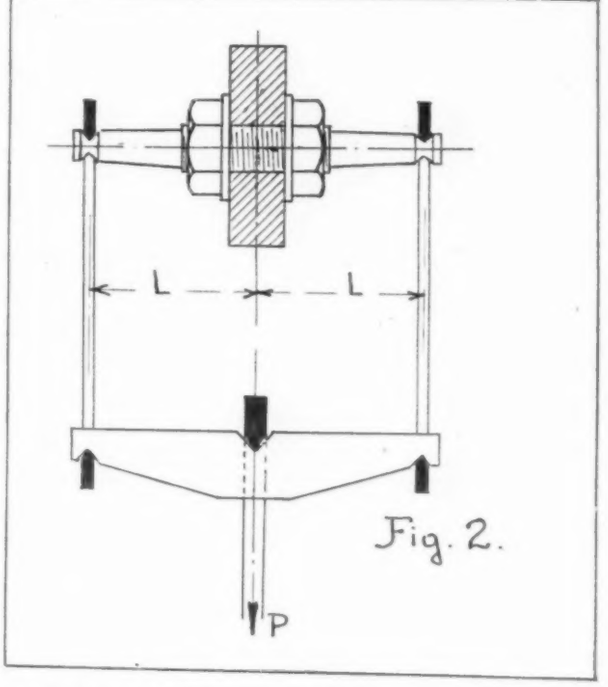


Fig. 2.

is a constant. The approximation is so close that there is no doubt about the generality of the law, particularly so if great care has been exercised in making the tests and, of course, if the specimen used is of uniform size and structure throughout.

This product is termed by the writer *the buckling moment of the beam*. For uniformly distributed loads and for special forms of loading the length function does not always remain, in its final state, expressed as the square of the length, as will be shown later. In view of those cases the buckling moment might be expressed more generally as the product of the load by a function of the

length. This is offered here as a convenient expression and if subsequent work by other investigators should lead to a better one, the latter should be adopted if at all beneficial.

The Third Law

Select several bars of the same kind of wood and having practically the same modulus of elasticity. Let three of these, for example, have the same uniform height of section h, but each of different uniform thickness b, Fig. 3 A.

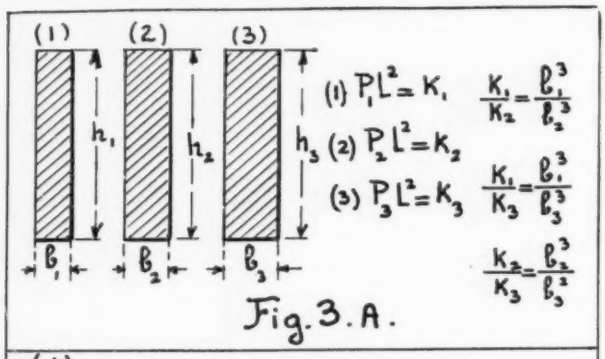


Fig. 3. A.

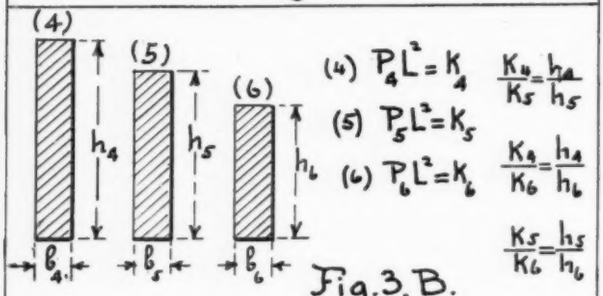


Fig. 3. B.

$\frac{K_1}{K_4} = \frac{b_1^3 h_1}{b_4^3 h_4}$ $\frac{K_1}{K_5} = \frac{b_1^3 h_1}{b_5^3 h_5}$ $\frac{K_2}{K_6} = \frac{b_2^3 h_2}{b_6^3 h_6}$, etc.

Calling K a general constant:

$P L^2 = K b^3 h$. Euler formula for a column held at one end and loaded at the other is: $PL^2 = \frac{\pi^2}{4} EI$. where I = least moment of inertia of the section $= \frac{b^3 h}{12}$.

Fig. 3. C.

Let three others be of the same thickness b, but each of different height h, Fig. 3B. After each of these bars is tested for the Second Law, and the results are compared, it is found that for the three first bars the constants, and consequently the loads, are proportional to the cube of the thicknesses; for the three others the loads are proportional to the heights of the section. A further comparison brings out the fact, Fig. 3C, that the loads are proportional to the products of the cube of the thickness by the height. This product multiplied by a general constant K is equal in each case to the value of the buckling moment. This constant remains to be determined.

Now, since the buckling load is the same for any regular position of the beam, when the latter is truly vertical it becomes a strut and is not any more subjected to direct bending action. The law established by Euler for the buckling of a column under similar conditions of fixation and of loading is expressed by a formula which contains all the factors uncovered by the above tests, plus the modulus of elasticity of the material and one sinusoidal function. The obvious inference is that the product of these two constant factors equals the value of K, the general constant. The proof is easily made.

The modulus of elasticity is readily obtained from simple bending tests. As a matter of fact it should be determined before proceeding with the buckling experiments, when the bars are still intact, and not marred by the jaws of the support. A specimen is placed horizontally flat upon two knife-edged supports, their distance apart being carefully measured. It is loaded at the middle just enough to make it quite rigid, but no record need be made of the load. The vertical distance from a point at the middle of the beam to a horizontal datum plane is very carefully measured. Then a known weight is added to the first load and the corresponding deflection is measured. Knowing the length between supports, the dimensions of the cross section, the second weight applied and its corresponding deflection, the modulus E is calculated by the well known flexure equation.

Introducing the value of the calculated constant in the equations derived from the experiments, it is found true to a most convincing degree of approximation. At least, that has been the experience of the writer when dealing with a large number of tests.

The Fourth Law

With the beam placed horizontally and fixed at one end, as before, one load is applied at the other end and another at some intermediate point of the length, Fig. 4. Either one may be increased until buckling occurs. It is found that each bending moment multiplied by its own lever arm may be considered as a component buckling moment. In other words, P×L squared, being the buckling moment for one single load, equals $P_1 \times L_1$ squared plus $P_2 \times L_2$ squared, and for any number of bending forces acting vertically along the beam the resultant buckling moment equals the sum of all the component buckling moments. This is a most important result.

This result may be extended in a most useful manner by taking the first law into account. Thus, when any number of forces act on the beam, as shown in Fig. 5, whether perpendicularly or obliquely to its longitudinal axis, but always along the action plane passing through the major axis of the section, the resultant or total buckling moment is the sum of all the component buckling moments, irrespective of the angle of direction of the forces, provided, however, that this angle, as shown is equal to or less than 90 degrees.

If the directions of the forces are not all along the plane of action, the above does not hold and the case becomes very complex because the beam is then subjected to twisting moments which are bound to cause local warpings and to weaken considerably the resistance of the beam to plain buckling. This question requires careful investigation and unfortunately does not seem susceptible of easy solution, if at all.

When the angle of direction of any one force is greater than 90 degrees the expression of its buckling moment takes a special form, which includes a function of that angle. As will be seen later on, this function comes in also for the smaller angles, but it vanishes automatically.

Composition of Forces vs. Combination of Effects of Forces

Fundamentally, one force acting upon one material point in space may be resolved into at least two components. The simultaneous actions of these components upon the point are equivalent to the single action of the original force. The same holds true of the composition of velocities. Very simple tests, however, bring forth a most interesting paradox, for which a satisfactory explanation has not yet been found.

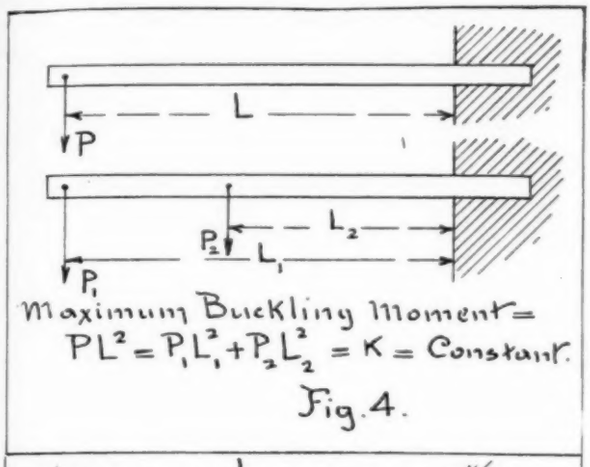


Fig. 4.

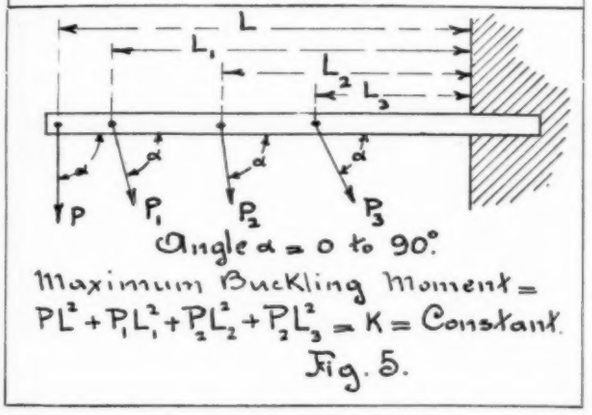


Fig. 5.

In Fig. 6 a beam is shown held obliquely. At the free end a suspension parallelogram is adjusted and connected to a loading platform A. On each side of the beam one wire is connected to the cross bar at the free end, and these running over two small pulleys at the other end, extend downward for connection to a second loading platform B. Any load placed upon this platform produces a true axial compression of the beam. Any load on A bends the beam, and when sufficiently increased buckles it. With each platform loaded the direction of the pull of the wires ceases to be truly axial, but because of the first law the effect of the load B is not altered; that would complicate the following demonstration, however, and for the purpose in view the curvature due to bending will not be considered here, the beam being assumed to remain straight.

If the buckling load P for the constant length L is ascertained according to the first law, it may be applied indifferently either at A or at B. The tests show that to be the case. If part of that load is applied on one platform it is also found that the load applied on the other platform and which finally brings out the buckling is precisely the difference between P and the first load. This demonstrates that, experimentally, and *for this particular mode of action, the effects of forces add.*

Assuming that the beam is placed at an agle of 60 degrees, and merely for convenience, that the buckling load is 41 pounds. If this force is resolved into two components, in strict accordance with usual practice, there will be one bending force of 20.5 pounds and one axial compressive force of 35.5 pounds, very nearly. Ordinarily it would be taken for granted that the effect on the beam would be the same whether the single force of 41 pounds is applied vertically or the two components be applied simultaneously at the same point of the beam. These tests show that that is not

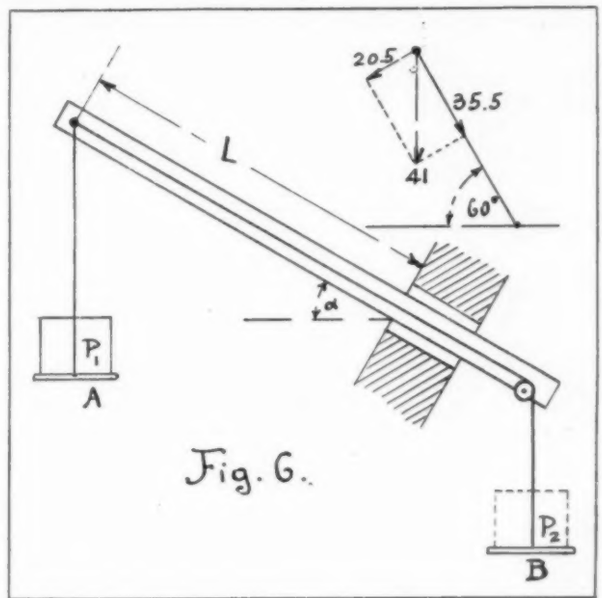


Fig. 6.

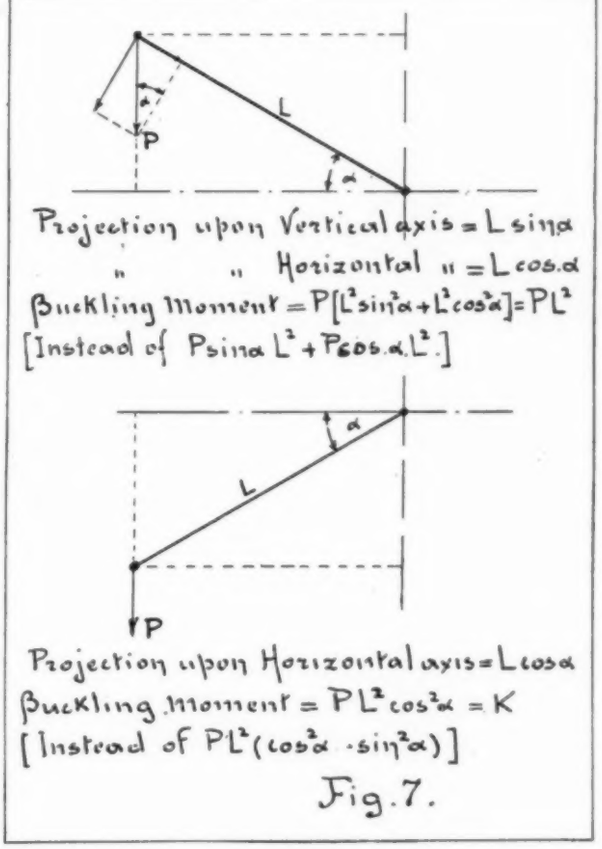

α
L
P
Projection upon Vertical axis = L sinα
" " Horizontal " = L cosα
Buckling Moment = P[L²sin²α + L²cos²α] = PL²
[Instead of Psinα L² + Pcosα L².]
α
L
P
Projection upon Horizontal axis = L cosα
Buckling Moment = PL²cos²α = K
[Instead of PL²(cos²α - sin²α)]

Fig. 7.

the case; on the contrary, if a load of 35.5 pounds is placed on B not more than 5.5 pounds can be applied on A in order to produce buckling. Moreover, the load at A may be truly vertical, or oblique, or again be normal to the longitudinal axis and in effect a true bending force acting along the direction of the bending component.

The obvious conclusion from these observations is that—in so far as buckling is concerned—it is incorrect and unsistance thereto one force by its components when the resistence thereto is a combination of molecular actions within the material of the beam.

For instance, assume that a vertical load of 41 pounds be a safe value for a given beam, the sum of the components, for a 60-degree angle, would be 56 pounds and the buckling moment 36.6 per cent greater than with the single vertical load, if the components were substituted for the latter.

Again, for the same beam, 41 pounds being the ultimate load, assume 30 pounds as a safe vertical load. If this force is replaced by its two components, 15 and 26 pounds, their sum is 41 and their simultaneous action would buckle the beams, whereas 30 pounds would not.

Complement to the First Law

The finding that the effects of the forces are additive instead of combinative, as expected, makes it awkward to understand and to explain the resistance of the beam held inclined above the horizontal and still more so when inclined below. For the upper condition, the simultaneous effects of the components would give, as per the equation in Fig. 7, the same buckling moment for two points only, when the angle equals zero or 90 degrees. For any intermediate angle the moment would be greater and would be maximum at 45 degrees with a value then 41.4 per cent greater than the value recorded. The slight discrepancies observed in the tests were fully within admissible limits, and the buckling loads practically identical for any angular position.

It therefore seems justifiable to consider the buckling moment for the beam in the upper position as composed of two simultaneous moments, one affecting the projections of L upon the vertical axis and equal to the product of the load P by the square of that projection, and another equal to the product of the load by the square of the projection of L upon the horizontal. This is equivalent to treating the vertical projection as a strut under axial compression and the horizontal as a beam subjected to simple bending. Each effect tends towards buckling the inclined beam, consequently the two may add. Since the expressions of the moments are functions of the angle, the sum of the squares of the projections reduce these functions to unity and they consequently disappear from the equation.

With the under position it is seen that the vertical moment does not tend towards buckling the beam, but, on the contrary, seemingly to steady it; it may therefore be omitted. The horizontal moment remains, and alone tends to produce buckling. Consequently the first law may be extended by an exception to the rule, and expressing that the buckling moment of a beam held inclined below the horizontal and loaded vertically at the free end equals the product of the load by the square of the projection of the length upon the horizontal.

Originally the writer was led, from the results of a few tests, to the conclusion that the vertical moment was to be subtracted from the horizontal, since it seemed to have a steadying effect; more recent tests have shown conclusively that it should be omitted. In other words, only the effects tending towards the same end should be added. The loads applied to the beam in the under position increased very rapidly with the angle; for instance, at 45 degrees, the load is twice that at zero, for the same length, of course. Besides, while the angle may be very carefully adjusted at the point of fixation, under such considerable loads the curvature of the beam is very pronounced, so that at the point of application the angle may be 5 to 10 degrees greater. The tendency of the beam to twist at several points of its length makes it very difficult to secure accurate results, and this explains the uncertain conclusions derived from the original tests.

Data Sheet of Buckling Moments

On a separate plate are shown fifteen cases of loading, and the formula for the ultimum buckling moment is given for each. The formulas expressing the effects of one or of several loads are derived from direct experiments, those dealing with uniformly distributed loads have been established by computation. For practical use a factor of safety must be introduced; its value depends on the mode of loading and of support. However, it would be safe for all practical applications to multiply the buckling moments by 2. Effectively, the tests show that, as the load increases gradually, the beam vibrates very vigorously laterally at half load, and it is only after the three-quarter load is passed that the vibrations become decidedly sluggish.

Throughout this article only beams of uniform rectangular cross-section have been dealt with, and the impression might obtain that the formulas given here do not apply to other forms of sections. It should be stated, however, that they apply equally well to any usual form. Numerous tests were made with T, I and U sections and the results were invariably expressed in function of the moment of inertia of the cross-section, referred to its vertical axis.

In a following article the great importance of the beam supports, of the attachments of the loads, and of the secondary moment induced thereby will be indicated for a few cases selected at random. The matter covers such a wide field, heretofore unexplored, it seems, that it is deemed proper to urgently request the co-operation of the engineering colleges in the pursuit of laboratory investigations, which are bound to prove useful mainly in two ways: in the elucidation of the elasticity behavior of materials and, for students principally, in a facile and true visualization and understanding of the application and effects of stresses.

Resignation of Reserve Officers

The War Department announces that the following policy will be observed and will be brought to the attention of reserve officers who tender their resignations before acceptance of such resignations:

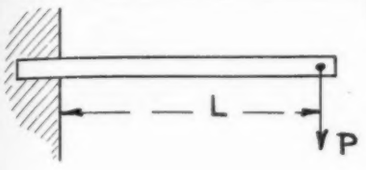
On account of the necessity for economy in expenditures and other considerations, it will be possible, in the immediate future, to call but a very small number of reserve officers to active duty for training purposes. Prior to June 30, 1922, no reserve officers will be called to active duty for training without his consent. Available funds and other considerations will probably make it impossible to call all those officers who request active duty for short periods of training.

During the time specified, to June 30, 1922, the organization of units of the Organized Reserve and the assignment of reserve officers thereto will be proceeded with. Such assignments will not demand a material amount of time of reserve officers.

The present number of reserve officers is insufficient. Those who hold commissions are urged to defer any withdrawal from the reserve contemplated by them until the Organized Reserve has been formed and definite policies for its training formulated. When such has been done and regulations governing the Officers' Reserve Corps have been published, reserve officers will have a better understanding of their obligations, duties and privileges, and will be better qualified to determine whether or not other interests necessitate their withdrawal from the Officers' Reserve Corps. The present reserve consists of veteran officers of the World War whose moral and material assistance in the building up of the Organized Reserve will be a very material factor in the efficiency of that force and the state of preparedness of our reserve forces.

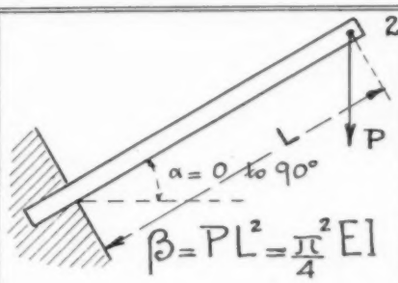
β = Buckling Moment for Beams of uniform Section throughout. E = modulus of Elasticity. I = Moment of Inertia of cross section referred to axis in plane of action of load. $\pi = 3.1416$.

1



$\beta = PL^2 = \frac{\pi^2}{4} EI.$

2



$\beta = PL^2 = \frac{\pi^2}{4} EI$

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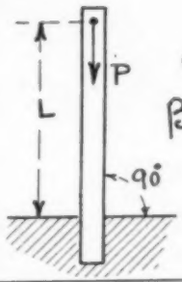
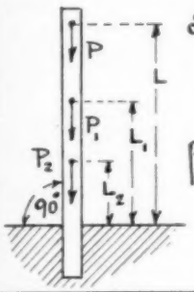


Axial load

$\beta = PL^2 = \frac{\pi^2}{4} EI.$

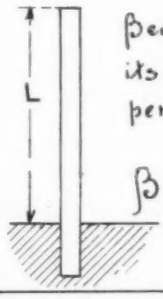
4



Several axial loads.

$\beta = PL^2 + P_1L_1^2 + P_2L_2^2 + \ldots = \frac{\pi^2}{4} EI$

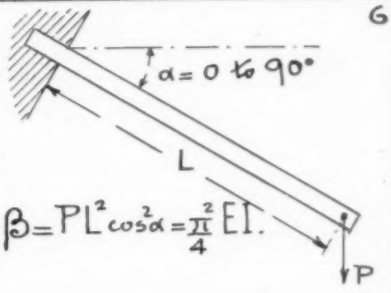
5



Beam sustaining its own weight p per unit of length.

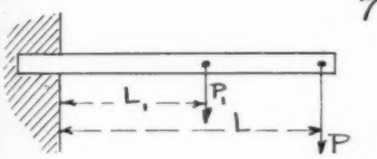
$\beta = pL^3 = \frac{3}{4}\pi^2 EI$

6



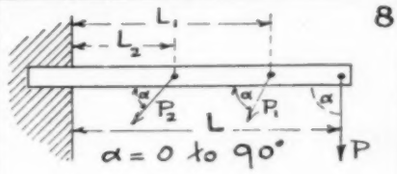
$\beta = PL^2 \cos^2\alpha = \frac{\pi^2}{4} EI.$

7



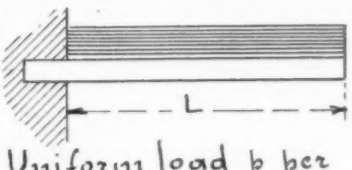
$\beta = PL^2 + P_1L_1^2 = \frac{\pi^2}{4} EI$

8



$\beta = PL^2 + PL_1^2 + PL_2^2 = \frac{\pi^2}{4} EI.$

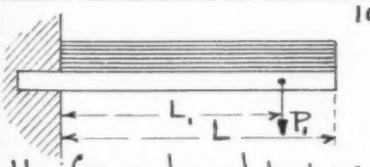
9



Uniform load p per unit length.

$\beta = pL^3 = \frac{3}{4}\pi^2 EI.$

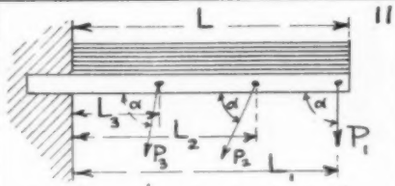
10



Uniform load p per unit length.

$\beta = \frac{pL^3}{3} + P_1L_1^2 = \frac{\pi^2}{4} EI.$

11



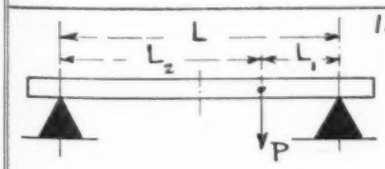
Uniformly distributed load p per unit length.

$\beta = \frac{pL^3}{3} + P_1L_1^2 + P_2L_2^2 + P_3L_3^2 = \frac{\pi^2}{4} EI.$

12

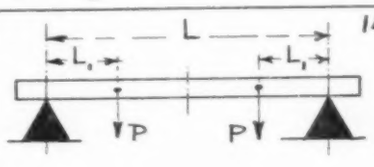
$\beta = PL^2 = \pi^2 EI.$

13



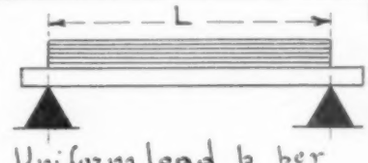
$\beta = PL_1L_2 = \frac{\pi^2}{4} EI.$

14



$\beta = PLL_1 = \frac{\pi^2}{4} EI.$

15



Uniform load p per unit length.

$\beta = \frac{pL^3}{2} = \pi^2 EI$

The Artillery Ammunition Problem

By

ARTHUR ADELMAN

Member A. O. A.

THE magnitude of the artillery ammunition question and the number of problems relating thereto which remain to be settled are not generally appreciated except by those intimately connected with this work. A round of ammunition appears so small when compared with the gun and carriage with which it is used that there is a general tendency to consider ammunition as merely a necessary component, required to make the gun function. As a matter of fact, the purpose of the gun is to start the projectile toward its target. The propellant in the round of ammunition furnishes the motive power and the projectile with its fuze and bursting charge produces the entire effect against an enemy.

The exterior of artillery ammunition presents a rather ornamental appearance which gives little indication of its highly complex internal structure.

Considering the problem solely from the mass standpoint, we may consider the 75-mm. field gun with carriage which weighs about 2,650 pounds. This materiel has a conservative accuracy life under normal conditions of about 10,000 rounds before major repairs, such as relining, are necessary. In the firing of these 10,000 rounds the gross weight of ammunition required is more than sixty times the combined weight of the gun and carriage. The weight of material hurled at the enemy is more than fifty times this combined weight, while the amount of high explosive carried to the target is more than six times, and the amount of propellant required to get the projectile to the target is more than five times, this weight.

The cost of the ammunition is thirty times that of the combined gun and carriage. For each gun and carriage produced a production of 10,000 each of projectiles, fuzes, cartridge cases, primers, adapters and boosters, etc., together with this large quantity of high explosive and propellant, is required. Failure to produce any one of these components or failure to assemble them will make the gun entirely useless. Furthermore, a let-down in the quality of material or in the correctness of dimension or in assembly of a single one of these components in any one of the 10,000 rounds of ammunition may result in a complete destruction not only of the gun and carriage but of the personnel manning the gun. Considering the large number of times each part must be produced, it becomes exceedingly important to eliminate every unnecessary operation and permit the greatest tolerance limits possible, and at the same time guard against extending these tolerance limits to the point where failures or prematures may occur.

That the magnitude of the ammunition problem was not fully appreciated prior to the war is indicated by the fact that the entire question was handled in the Ordnance Office in connection with the cannon problem. Not a single person was assigned to give undivided attention to ammunition. At Frankford Arsenal, development was more or less incident to production. Funds were allotted for a certain quantity of materiel and the development entirely tied up with this production. Firings were limited to the minimum so as not to encroach upon the quantity which it was estimated would be produced for service with the funds appropriated. The fact that not enough firing had been done in testing ammunition was clearly shown by the number of difficulties encountered early in the war and the rapid improvements which were made as soon as the ammunition really began to be fired in quantity.

Improvements in the rotating bands of projectiles which started soon after the outbreak of the war and which resulted in great increase in range and even greater improvement in accuracy are already familiar; also, improvement in shape of the projectile which resulted in doubling the range of the 6-inch gun, the projectile hastily designed early in the war reaching only about 15,000 yards, and the latest projectile reaching nearly 30,000 yards.

It may not be out of place at this time, now that the necessity for propaganda which would credit marvelous discoveries to science is past, to state that the improvement

relative to rotating bands was entirely a development incident to experimental firing and recovering projectiles for examination at the proving ground and not to theoretical calculations. In other words, the fringing of the rotating band was noted from the results of firing through jump cards and from observation of recovered projectiles, and the remedy applied was the use of ordinary judgment and not higher mathematics. The improvement in design of projectiles whereby the range was more than doubled was also more a result of cut-and-try methods than of applied scientific principles. Work on the scientific principles of design was however inaugurated at that time in the form of wind tunnel or air stream tests with different shaped projectiles and extended firings through jump cards. These tests are still being carried on, and it is expected that these researches will ultimately result in further improvement in both range and accuracy and will place the principles of design on such a basis that the results can be predicted before firing, instead of requiring the old cut-and-try methods.

It may also be of interest to correct at this time the impressions that seem to be common that no work toward improving the ballistic qualities of our shell was undertaken prior to the war. Even without a definite development program and no personnel assigned exclusively to ammunition work as a whole, let alone the important branch of the subject—ballistics—considerable progress had been made. The first projectiles for our modern artillery, produced from 20 to 30 years ago, were designed with a radius of head of about two calibers. This gave a good shape for armor penetration and apparently gave as much range as desired, since range tables were rarely extended to the full range permitted.

About 1903, a blunt cap was added to these armor piercing projectiles which increased the armor penetration but reduced the ballistic qualities. About 1905 or 1906, we tested the first long pointed projectile in the shape of a small arms bullet which developed into the 1906 ammunition for the service rifle. Similar shaped projectiles for 3-inch, 6-inch and 12-inch guns were laid down about 1907 and tested. The results with the 6-inch gun were quite as startling as some of the later results which have been so much commented upon. Firings were made at an elevation of 7 degrees and a range of about 12,800 yards was obtained as compared with about 8,000 yards for the service projectile.

With the 3-inch field gun and the 12-inch seacoast gun decided improvements in range were obtained though not nearly so great a percentage as with the 6-inch on account of the velocities being lower. At this time the question of range was entirely subordinate. The sole idea of a sharp bullet in the .30 caliber was to obtain flatness of trajectory and therefore greater danger space. With the artillery, flatness of trajectory and increased remaining velocity at a given range, resulting in greater chance of hitting and greater armor penetration were the considerations. There appeared to be no great requirements for the sharp projectile with mobile artillery.

The 3-inch field gun was practically the only caliber at that time and shrapnel was considered as the most suitable ammunition. There was considerable difficulty in obtaining satisfactory armor piercing qualities with long pointed shell, this being finally accomplished by leaving the body of the shell with armor piercing cap as it had been designed and obtaining the long point by the use of a false cap.

The first suggested use of the false cap in our service was in 1907, but the development with the solid type continued until 1908 when, due to unpromising results, experiments started with the false cap. In 1910, designs were prepared and steps taken to have all projectiles in the service modified by the addition of a false cap to increase the ballistic qualities. The modification was considered primarily from the standpoint of altering projectiles on hand and for practical reasons the effective radius of head was about five calibers instead of seven calibers used in the preliminary tests.

It was not until about the outbreak of the war that the question of range became a serious factor. This was probably due to the fact that until the use of the aeroplane in directing fire the range was limited by fire control equipment. Prior to the use of the aeroplane, improved methods

A "Premature."
Disastrous results are caused by improper functioning of even a single component of the scores required to assemble one complete round

of observation and fire control to effectively utilize ranges already permitted were considered of more importance than attempts to increase range.

In 1916, the 12-inch armor piercing projectile with false cap having a 9-caliber radius was laid down and orders placed. This projectile was designed to increase the range of certain fixed batteries permitting only limited elevations of the gun. This is about as good a projectile ballistically as has yet been laid down except possibly for the improvement resulting from boat-tailing, and no satisfactory method of applying boat-tailing to armor piercing projectiles has yet been devised. Experiments with boat-tail projectiles were started about 1912 or 1913 in a small way, the first results being unsatisfactory. From the present knowledge, it appears that the unsatisfactory results were due to using too great an angle. In 1915, 6-inch projectiles boat-tailed less abruptly were fired with satisfactory results.

Certain problems brought out during the war, or greatly emphasized by the events of the war, will be briefly discussed. The requirements for improvements in connection with ammunition as brought out by the Caliber Board Report (Westervelt Board) relate primarily to increased

safety, increased range, increased accuracy, and increased effect at the target. To these may be added increased ease of production or at least no increased difficulty.

Taking up the subject of increased safety, we will consider first the fuze, since this is the component which is almost always blamed for every premature. To meet safety requirements, fuzes of the "bore-safe" type are being developed. By a "bore-safe" fuze is meant one in which, besides the usual safety feature, whereby the primer is not permitted to be struck by the firing pin in the bore, the explosive elements are so separated that either the primer or detonator, or both, might be set off by shock without igniting the booster charge of the fuze. They are not brought into position where the booster would be ignited until after the projectile has left the bore. This results in not only a safer fuze to fire, but a safer fuze to store and to transport. It permits the issue of ammunition in the fuzed condition, since ammunition in dumps with this type of fuze would be no more susceptible to destruction by enemy fire or bombing than unfuzed projectiles.

Another method of increasing the safety is improvement in the quality of the explosive and improvement in the method of loading. Both of these subjects are being actively studied. It is known that the explosives produced during the war were not up to the desired standard due to the necessity for somewhat sacrificing quality to obtain quantity; also, the methods of loading in vogue, while the best available for the large quantity production required, did not meet the ideal requirements as to safety. The problem is, therefore, to obtain better types of explosive and better methods of manufacture, and also improved methods of loading without sacrificing production requirements.

Another method of increasing safety is the more careful production of the shell itself. A 100 per cent hydraulic test at pressures corresponding close to the elastic strength of the projectile should eliminate the structurally weak shell without greatly interfering with production, assuming that provision for this test is made when the plants are laid out.

There are only two methods of obtaining increased range —one by increased muzzle energy, which means increased power of the gun, the other by improvement in the shape of the projectile. Reference has been made above to the change in design of projectile which more than doubled the range in the 6-inch gun, although it may be stated that the projectile which gave the shorter range was by no means as good ballistically as the type which was tested as early as 1907. When it is considered that even with the best projectile yet produced the range does not equal one-third of that which would be obtained by firing *in vacuo*, it is seen that much further improvement should be possible. This small percentage of actual range to theoretical range *in vacuo* is obtained with high velocity guns.

With the low velocity howitzers and mortars, the range already obtained with projectiles of rather poor ballistic shape is from 90 per cent to 95 per cent of the range *in vacuo* so that little further increase is possible. In order to bring out the importance of improvements in the projectile in connection with increased range, let us consider how the 15,000-yard range with the new 75 mm. field gun is being obtained. Going back to our old 3-inch field gun, model of 1902, we find a range of about 6,000 yards but a possible range of about 10,000 yards by changing the carriage so as to obtain higher elevation. This same type of projectile in the new 75 mm. field gun would give a range of about 11,500 yards, or only 15 per cent increase, although the energy developed by the gun has been increased 64 per cent. With the improved projectile it is expected to obtain the other 3,500 yards. Considering the problem in another way, the model of 1902 field gun would give a range of about 12,500 yards with the new projectile giving 2,500 yards increase for the 64 per cent increase in muzzle energy instead of 1,500 yards.

Improvements in accuracy should result from proper shell design; that is, proper shape and balance coupled with suitable twist of rifling. The rotating band should be non-fringing. Improvements in accuracy should also result from closer fit of the projectile in the bore and from closer tolerances on some of the important dimensions. This question of tolerance was one of the most difficult encountered during the war, and was never settled to the satisfaction of either the designer or the producer. One of the reasons why the problem was so difficult was that there was no information available as to just how much the tolerance of an individual dimension would affect the accuracy. Neither was there any agreement between the designs of our allies as to which dimension should be held to a close tolerance.

In order to obtain increased production, there was a constant tendency toward increased tolerance on almost every dimension. It was very confusing to the manufacturer and to the designer to find such a wide divergence of opinion as to the practical limits. For example, the Ordnance Department had prescribed a very close tolerance on the rotating band and its location; also, close fit of the bourrelet with a close tolerance on that dimension. The French appeared to lay much stress on the center of gravity and had rather close tolerances on this element. The British on the other hand had a method of repairing light weight shell which permitted the addition of a metal plate to the base end. The thickness of this plate could be as much as .4-inch for the 6-inch with a weight of one and one-half pounds and a thickness of 1.4 inches for the 14-inch with a weight of 21 pounds. This method of repairing not only changed the location of the band but the center of gravity, and it could not be stated at the time that British ammunition was not giving satisfactory accuracy.

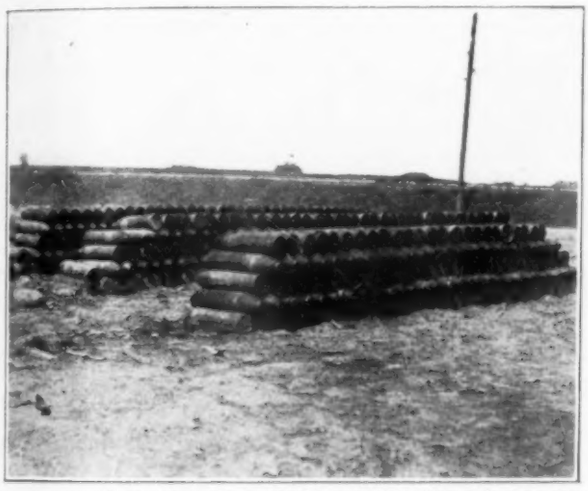
With reference to the proper fit of the bourrelet, the British had no bourrelet on most of their projectiles. The French had a rather loose fit and raised objection to the closeness which we originally prescribed for our 75 mm. projectiles. These are merely examples of the lack of agreement, many more of which might be mentioned.

In order to obtain more definite information on which to base future tolerances on projectiles, a large program has been undertaken in which one-half of the projectiles have been selected with care so that each dimension represents about the mean prescribed. Other projectiles are in groups which have all the dimensions except one at about the mean prescribed. Several groups are selected which have this one dimension successively varied up to the limit and sometimes beyond the limit of the prescribed tolerance. The program is rather an extensive one and when completed should show which dimensions are the important ones and how much tolerance can be permitted without greatly affecting the accuracy.

It has already been determined that location of the band is of considerable importance and also that the close fit of the bourrelet is one of the most promising means of increasing accuracy. Relative to the tolerances on projectiles, the problem was perhaps more difficult than on almost

any other piece of ordnance. As a general thing, in a fuze or breech mechanism the tolerance had more relation to actual functioning or strength of part. With the projectile, for the most part there was no question of strength and no question as to satisfactory functioning in so far as functioning could be judged at the gun. The main question was as to the effect on accuracy, and little or no information was at hand covering this point. Uniformity of muzzle velocity is also an important item in accuracy of fire. Uniformity of velocity is being investigated along the line of better ignition and in the development of a non-hygroscopic powder which should function better under service conditions than the present propellant.

Relative to increased effect at the target, development is being pursued along the line of increased certainty of action; that is, less "duds" and also less low order explosions. This is a combined problem of improved fuze design, improved loading of both fuze and projectile and possibly a better explosive. Increased effect by a better ratio between explosive to weight of metal in the projectile is also a project which is being studied, but it appears probable that the question as to the relative importance between blast effect from a large bursting charge and destructive effect from fragments of the shell wall is one on which there will always be a divergence of opinion. Another method of increasing the effect is in the development of a more uniform time fuze for anti-aircraft guns. Mechanical or clock-work fuzes are being developed to fulfill this function.



When any part of a single round deteriorates in storage—

"Mass Detonation" converts the dump into a crater

The difficulty in the development of such a fuse lies in the fact that the mechanism must have the accuracy and delicacy of a reliable watch, and at the same time must be so ruggedly constructed as to withstand the stresses produced by firing from a high-powered gun. These stresses are due both to linear acceleration, which is equivalent to about 3 pounds for every grain of weight, and rotational velocity, amounting to over 30,000 revolutions per minute. The Waltham Watch Company has developed a fairly satisfactory fuse, and other companies have made considerable progress in their development projects.

Improvement in the effect of armor piercing projectiles is along the line of obtaining penetration of armor at oblique impact of the projectiles. A few years ago projectiles were purchased under specifications requiring penetration at normal impact or, at the most, impacts at 10 degrees from normal. The naval engagements of the war brought out the fact that hitting at such favorable angles was improbable, so that we now require that projectiles penetrate armor plate of thickness equal to the caliber at angles of impact of from 20 to 25 degrees. Improvements are also being made in the methods of loading armor piercing projectiles and an improved fuze which will withstand the increased shock of impact against armor due to inclined impact and burst the projectile behind the plate is under development.

A fuse of this type is one of the greatest needs at the present time, and it can be quite positively stated that no country has yet produced a reliable fuse. The problem presents many difficulties, due to the severe stresses which such a fuse must withstand in passing through an armor plate without rupture of any of the parts or sufficient deformation to make the explosive elements function before the desired delay has been obtained. It is confidently expected that the development of such a fuse by the Army Ordnance Department will soon be an accomplished fact, and that with this development the armor-piercing projectile of the United States Army developed during the past few years will be superior to any other in existence in range, accuracy, armor penetrating qualities and effectiveness after penetration.

Present problems cover a considerable range of subjects, including interior and exterior ballistics, chemistry of explosives, mechanical engineering, and a general knowledge of metallurgy. As I shall endeavor to point out in a subsequent article, tackling these problems can not be deferred. There is a widespread popular belief that, as a result of the World War, we accumulated sufficient artillery ammunition to last a generation. It is true that we have adequate reserves of the more important calibers, but how long they will continue to be safe in storage and serviceable in action it is impossible to predict. Even provided improvement in quality of ammunition by other nations does not render our present stocks in a measure obsolete, we are confronted with problems of abnormal deterioration due to the emergency conditions under which the greater part of these reserves was manufactured and inspected. Inferior artillery ammunition exacts its toll not from the enemy, but from our own forces. Inaccurate ranging in barrage destroys our advancing waves it is intended to protect; "prematures" effectively destroy gun crews—the wrong gun crews—our own artillerymen. Under shelter of our present reserves, now is the time to attack the artillery ammunition problem.

Fig. 1. Field of Silhouettes for determining fragmentation

Testing Aircraft Bombs

By

ARTHUR W. EWELL
Member A.O.A.

[Major Ewell was directly connected with aircraft armament development during the war. He wes in the A. E. F. as part of the Aircraft Armament Section of the Ordnance office and was selected to return to this country to assist in the development of bombs. Through his efforts the testing facilities at Aberdeen were created; great credit is due him for the inva'uable assistance he rendered in this particular. It was through his efforts that the new development on bomb fuses was undertaken. He, more than any other, brought to this country the knowledge of what bombs really should and had to do.

IT is hardly necessary to emphasize the importance of aerial bombing. The use of bombs steadily increased throughout the world war. Important improvements in bombs and aircraft at the time of the armistice promised an enormous consumption of bombs during 1919. Even at the present time their use continues in appreciable quantities in the various minor wars still in progress, particularly against nomadic tribes in Africa and Asia.

Aerial bombing possesses two great superiorities over artillery, namely, greater range and visual attack. The Germans shelled Paris from a distance of eighty-odd miles but they succeeded in hitting their target only on account of the great area. At the time of the armistice the English were fully prepared to bomb Berlin, a range beyond the wildest imagination of the artillerist, and the bombers would have sighted directly upon selected portions of the city.

Granted the importance of bombing, the importance of exhaustive bomb testing may not be fully recognized. It is however, only necessary to point out that the cost of all the tests which should be made upon the bombs used in a particular raid would generally be less than 1 per cent of the total cost of the raid, disregarding the risks taken by the crew. How insignificant this is compared with certainty of functioning and increase in effectiveness!

The public is prone to think of aerial bombing as primarily against buildings, railways, etc., the obvious reason being the newspaper prominence given the Paris and London raids. As a matter of fact the majority of the bombing in the world war was against troops. During 1918 the number of bombs dropped against personnel was about 95 per cent of the total and although the personnel bombs are small the actual weight of bombs dropped was also in excess. Therefore, owing to their importance, we will first consider testing personnel bombs.

The more nearly actual conditions of war are approached, the more valuable the tests. The Romans would probably have dropped their experimental bombs among regularly spaced prisoners in the amphitheatre and the gate receipts would probably have covered the expenses of the tests. In deference to modern sensibilities the prisoners are replaced by silhouettes or manikins, as shown in Fig. 1.

These are formed of crossed boards and in height and in width, as viewed from different directions, correspond to the height and breadth of the average man. The actual distribution is unimportant provided it is accurately known.

In order to expedite the tests and to economize in bombs, they are dropped from a practically stationary balloon or dirigible which is maneuvered until a vertical collimator* shows that the center of the silhouette field is directly beneath. The point of impact and the particular silhouettes perforated by the fragments are carefully marked upon report forms which show the location of each silhouette. Concentric circles are drawn on the form with the point of impact as a center. The area of the inner circle and of each ring is multiplied by the ratio of the number of perforated silhouettes to the total number in the particular area. (The outer ring is sufficiently far from the point of impact that relatively few silhouettes in it are perforated.) Thus the sum of three products of areas by ratios gives an area over which a silhouette is certain to be perforated. It is customary to measure areas in terms of 100 square meters as a unit and to divide the final area by the weight of the bombs in kilos, thus expressing the efficiency of personnel bombs as so many 100 square meters per kilo.

If a particular type of personnel bomb shows up poorly in this final test the trouble may be in the fuse, the explosive, the metal of the case or its shape and thickness. Therefore these final tests with the silhouettes are always preceded by preliminary tests in which these individual characteristics can be studied separately. The explosive and metal are tested by exploding the bombs statically in a sandbox, the fuse being replaced by an electric blasting detonator. From the number and average size of the fragments the quality of fragmentation is determined. The velocity and distribution of the fragments is preliminarily ascertained by exploding the bomb statically, in the center of four quadrantal panels, the distances from the bomb being 10, 20, 30 and 40 meters, respectively. A view of the panels is given in Fig. 2. The height of these panels is the same as that of the silhouettes and the efficiency is calculated similarly. The average width of a man being taken as one-third of a meter, the effectiveness of the bomb at the second panel, for example, is taken as unity if there are at least three perforations per meter of length. If there are less than this number, for example, but two per meter, the effectiveness is taken as two-thirds and the area of the ring between the first and second panels is

*[A telescope (usually of unit magnification) with the bubble of a spherical level in the focal plane.]

multiplied by two-thirds and so on. Since each panel is at the extreme edge of a particular zone, the efficiency with the panels will be less than with the silhouettes which are distributed throughout the zone.

After the fuses of personnel bombs have passed all preliminary laboratory trials they are tested in bombs which are dropped upon all types of surfaces. Their action must be very instantaneous, resulting in the smallest sort of a crater even when dropped from great heights, the ground being merely "brushed" by the explosion.

Demolition bombs are primarily intended for destruction either of means of communication (roads, railways, bridges, docks, etc.) or buildings. In both cases the effectiveness is largely dependent upon the blast effect, although the fragments afford considerable damage as was evident in any bombed city in Europe.

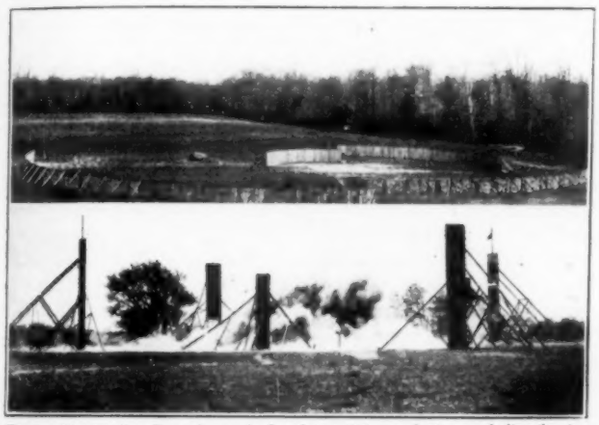


Fig 2. Above: Quadrantal panels for determining velocity and distribution of fragments
Below: High panels for determining blast effect

The blast effect may be roughly determined by the size of crater produced. The bomb may either be buried and fired by an electric detonator or it may be dropped with a fuse retarded to permit maximum penetration before explosion. While crater tests are very necessary, they do not afford a sufficient test of the blast effect because so much depends upon the nature and condition of the soil. Moreover, they give no information about how the blast is distributed. Accordingly, specimens of all types of new demolition bombs are exploded statically in the position in which they would strike the ground and the amount of the blast is measured by blast meters distributed at different heights, azimuths and distances about the bomb. There are always a sufficient number to permit the destruction of several without loss of the test. A very simple and quite satisfactory type of blast meter consists in a frame having a dozen or more circular holes varying in size from about a quarter of an inch to several inches in diameter. Each hole is covered with paper of specified quality. The magnitude of the blast is measured by the smallest disk of paper burst.

The distribution, velocity and size of the fragments is determined at the same time as the blast. The bomb is surrounded by high panels of two-inch oak at various distances. After the explosion the locations and size of the perforations are observed. The velocity of the fragments are determined by Aberdeen chronograph screens set up at different distances. These high panels are shown in Fig. 2.

Bombs designed for destruction of means of communication must be able to penetrate very hard surfaces without cracking or buckling of the case and the fuses and delays must endure the terrific blow resulting from impact upon an unyielding surface. These qualities are tested by

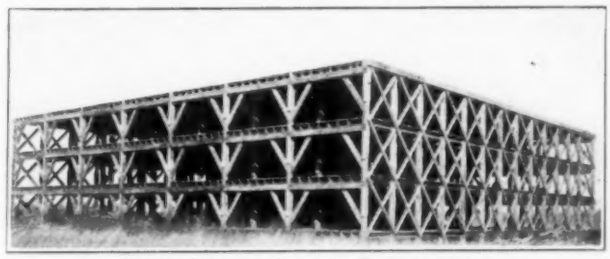


Fig. 3. Structure for testing floor penetration

dropping sand-loaded bombs from various altitudes upon a concrete surface with a crushed stone foundation. For fuse tests both the fuse and the booster are loaded.

In the early part of 1918 the French Air Service was able to conduct practical tests upon buildings. The Germans in the onrush of 1914 left a French sugar factory near Meaux in a condition which justified its further destruction by the French for the test of bombs destined for German factories further east. Unfortunately, they were inconsiderate enough to shoot down two successive balloons from which the bombs were being dropped upon the sugar factory and this ideal target was discreetly abandoned.

The principal characteristic of bombs intended for buildings are, first, a case which will penetrate successive floors without injury, no matter how much the bomb may be deflected, and second, two fuses, one of which is retarded and the other is selective. A proper selective fuse will not function when a relatively light structure like a roof or floor is struck but will function instantaneously when a

(Continued on Page 269)

Fig. 4. Aeroplane view of balloon dropping fragmentation bombs

Some Remarks on Poisson's Ratio

By

F. C. LANGENBERG

Member A. O. A.

THERE has recently been published in the ARMY ORDNANCE an article by Maj. Albert E. Guy on the subject of "Auto-frettage." In this paper certain statements are made which, in the opinion of the present writer, are not substantiated by experimental evidence now available.

Quoting from this paper:

> Preliminary experiments conducted at the Bureau of Standards and at the Watertown Arsenal have already proven so successful as to permit the writer to advance several facts of basic importance to the engineering profession. For instance, it seems established that there is only one elasticity in a body, that of the mass affected by stress, instead of the old notion of tensive, compressive, torsive, etc., elasticities.
>
> The so-called Poisson ratio of lateral to axial strains instead of being taken as practically constant, with a value between one-fourth and three-eighths, varies between zero at no load to about one twenty-sixth at the elastic limit, and thence from to about one-half toward the rupture point.

Referring to the first paragraph of this quotation, the passing of the elastic or proportional limit in any crystalline body is always accompanied with the appearance of slip bands on the crystals of the body which is under stress. The character of these slip bands is well known, and these slip bands are similar, regardless of the nature of the stress which produced the deformation. If the engineering profession still holds, as one would infer from Major Guy's discussion, that the mechanism of plastic deformation differed with the nature of the stress, then the engineering profession has not made use of data already available. It would not seem a new and novel discovery that the elastic limit did not vary with the nature of the applied stress.

Regarding the second paragraph of this quotation, the present writer cannot feel convinced that any data obtained at Watertown Arsenal has indicated that Poisson's ratio is not constant, or that it has the values indicated by Major Guy.

It might be of interest to discuss some of the exceedingly accurate work of Prof. P. W. Bridgman in connection with compressibilities and its relation to Poisson's ratio. In "The Contributions of the Jefferson Physical Laboratory of Harvard University," which were published in the *Proceedings of the American Academy of Arts and Sciences*, the compressibility of several samples of steel was reported. The writer is taking the liberty of quoting certain statements and data from this paper.

The linear compressibility of a sample of Bessemer rod which had been annealed was found to be 1.722×10^{-7}. Dr. Bridgman states, regarding this rod, "No set was observed in this piece on the first application of pressure, which is, perhaps, evidence of the freedom from internal strain and, to a less degree, evidence of equal compressibility in all directions."

He likewise determined the compressibility of two pieces cut from a boiler plate, both in the direction of, and at right angles to, the direction of rolling. The linear compressibility of the lengthwise piece was found to be 1.766×10^{-7}, and of the transverse 1.767×10^{-7}. Dr. Bridgman states that the probable error of the compressibility in either case is about .2 of 1 per cent. He further states as follows: "No claim is made that this settles the question of the equal compressibility of metals in all directions." He made further observations on a bar of high carbon, annealed tool steel and found the linear compressibility to be 1.750×10^{-7}.

Another interesting observation was made as follows: "It is to be noted that neither the steel nor the aluminum shows any tendency to become decreasingly compressible at higher pressures." When we realize that the pressure range employed by Dr. Bridgman was 6500 kgm. per square centimeter, which is equivalent to 92,450 pounds per square inch, and furthermore bearing in mind that these experiments were exceedingly refined, and carried out by the greatest authority on high pressures in the world, it becomes almost impossible to believe that Poisson's ratio has any other than a constant value within the elastic range. If the compressibility of the samples referred to was other than a linear function, the statement made by Major Guy might be warranted, but in view of the exceedingly accurate scientific data referred to his position seems entirely tenable.

It might be of interest to compute Poisson's ratio from the data obtained by Dr. Bridgman, on the assumption that steel is isotropic—that is, having identical properties in all directions, such as glass, water, etc. The assumption that steel within the elastic range is isotropic cannot greatly diverge from actual conditions. Crystals of any substance are, in general, anisotropic, and, furthermore, they are geometrically anisotropic, but a body composed of crystals may, in the aggregate, be either anisotropic, such as slate, or it may be practically isotropic if the crystals vary in orientation throughout the mass.

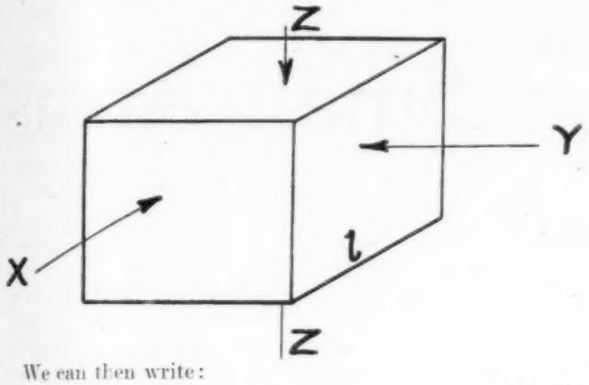
Consider for a moment a mass of steel. Assume that each grain is composed of anisotropic crystals, and as the orientation of each crystal in each grain is identical, the grain itself would be anisotropic. In a mass of steel, let us say one inch square, we can assume, after a normal anneal, that the number of grains is between one hundred and two hundred million. Although each grain has been assumed anisotropic, the cube of steel referred to must certainly very closely approach isotropic, as there is no relation between the orientation as one proceeds from one grain to the next.

In the theory of elasticity as applied to steel, it has always been considered that the material was isotropic—that is, for example, Young's modulus is considered the same regardless of direction. Poisson's ratio also assumes isotropy.

From many hundred tests taken in different planes and in different directions in forgings, the writer is quite convinced that Young's modulus is constant regardless of direction within the limits of ordinary measurements as ap-

plied in the testing material laboratory. This limit of accuracy can be fixed at approximately 2 per cent. Prof. Bridgman has already determined that the compressibility in a sample of Bessemer plate was the same, both in the direction of rolling and at right angles to this direction. The steel in a plate is in a condition which would show anisotropy, if this condition existed, much more readily than in the normal forging, due to the excessive amount of rolling which it has received in one direction.

Assume a cube of steel one inch square, and allow it to be subjected to unit stress P over its entire area.



We can then write:

$$1_x=\frac{1}{E}(X-Yr-Zr)$$

But under conditions of Dr. Bridgman's experiment X, Y and Z are equal. Placing X, Y or Z equal to some definite pressure

$$P=5000 \text{ kgm. per sq. cm.}$$

$$1_x=\frac{P}{E}(1-2r)$$

1_x at 5000 kgm. per sq. cm. or 71,100 lbs. per sq. in. is equal to $(1.767\times10^{-7})\ (5000)=.0008835$. The value of the linear compressibility 1.767×10^{-7} is chosen from the values obtained on the Bessemer plate, namely, 1.766×10^{-7} in the longitudinal direction and 1.768×10^{-7} in the transverse direction. $1_x=.0008835$ represents, therefore, the proportional decrease of length under a pressure of 71,100 lbs. per sq. in., and on an assumed cube 1 in. square a uniform pressure of 71,100 lbs. per sq. in. would decrease the length .0008835 inch.

Assuming E=30,000,000 lbs. per sq. in. $1_x=\frac{P}{E}(1-2r)$ must be written $-1_x=-\frac{P}{E}+\frac{2Pr}{E}$ as P along 1_x is compression.

$$\frac{P}{E}-1_x=\frac{2Pr}{E}$$

$$r=\frac{P-E1x}{2\ P}$$

Substituting

$$r=\frac{71{,}100-30{,}000{,}000\times.0008835}{142200}$$

$$r=.313$$

or not far from the value $\frac{1}{3}$ used in the present gun formulæ. The value of "r" thus obtained may not be accurate, but it possesses at least sufficient merit to warrant a more thorough study, which is now in progress.

[*Author's Note.*—The values for compressibility used in this paper have been subsequently subjected to slight corrections by Dr. Bridgman, but this will not affect the validity of the calculations. The correct values on a number of samples will soon be submitted to the Ordnance Office.]

Testing Aircraft Bombs

(Continued from Page 267)

pavement or hard ground is hit. Thus a bomb which hits a building will penetrate a large number of floors before exploding, while if the building is missed, it will explode instantaneously outside the building and not waste a large proportion of the blast and fragments in the ground. Fig. 3 illustrates the Aberdeen Test Building. The target being quite limited, it is customary to drop the bombs from a balloon or dirigible. Fig. 4 shows the manipulation of a balloon.

If this entire issue were devoted to bomb testing, the tests of all the other types of bombs—incendiary, gas, armor-piercing, torpedo, illuminating, etc.—might be described, but the above brief description of some of the tests for the more important types must suffice.

Whatever may be one's view regarding universal military service, the size of the regular army, etc., every reasonable person must acknowledge the importance of the highest possible development of all offensive armament. The writer was privileged to follow bomb testing in France and England during the last year of the war and at Aberdeen since the armistice. It is with the greatest pleasure and satisfaction that he can state without qualification that the American Army possesses, in the personnel of the Aircraft Armament Division of the Ordnance Department and the equipment at Aberdeen Proving Ground, facilities which are unsurpassed in any other country.

Eyes for Tanks

During the World War tanks were not always able to render maximum assistance, due to the poor facilities for observation afforded the tank operators. Effort has been and is being directed toward providing something which will not only give better observation, but will also provide protection to the observer at the same time.

In the first tanks used during the war, observation was obtained by looking out of port holes, which meant that the observer was in great danger of being injured or possibly killed by enemy fire. Later these observation slits were protected by means of a movable shutter, so that varying degrees of opening could be obtained, the smaller opening affording the greater degree of protection to the observer.

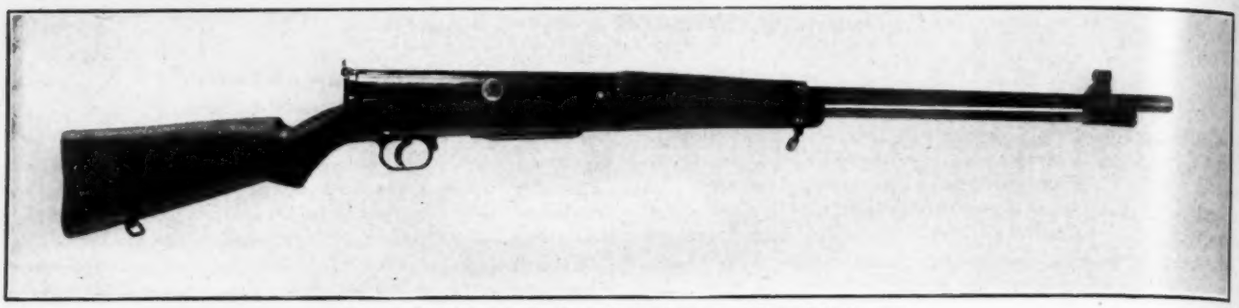
Some of the British tanks were equipped with a periscope device for the driver, which was so arranged that he had good observation directly ahead. The objection to this form of periscope was that it was easily broken, became dirty very quickly, and permitted observation only in a very narrow range directly in front of the tank.

Practically all of the later British tanks, as well as the Anglo-American Mark VIII Tank, obtained their observation through the use of observation slits and small hand periscopes. Several of these periscopes were provided for each tank, and openings made in the roof of the tank, so that if enemy fire was too severe the periscope could be pushed up through a hole in the roof, giving protection to the observer; otherwise the observation slits were used.

In general, the facilities for observation used in tanks during the war were wholly inadequate; if tanks had been given better eyes, they would undoubtedly have rendered better service.

One solution to this difficult problem, which is now receiving careful study and consideration, is based upon the stroboscopic principle. The principle of the stroboscope is very simple. Almost every one has observed when walking rapidly beside a picket fence that the pickets seem to have little effect in obscuring objects beyond the fence. The stroboscope operates on almost exactly the same principle and consists of a revolving plate, or cylinder, with slits cut in it. The retina of the eye will hold an image for approximately one-tenth of a second, and in this revolving plate, or cylinder, the slits are so arranged and the speed is governed so that a new slit will be presented to the line of vision within this time interval, giving the effect of practically continuous vision. In the use of this principle for observation and protection in tanks, it is proposed to make the slits sufficiently narrow to keep out the cores of armor-piercing bullets and to reinforce these slits with the backing of non-shatterable glass, so that the moulten lead, or splash resulting from the impact of the bullet on the revolving screen, will not get through and injure the observer.

This form of observation and protection seems to have tremendous possibilities, and it is hoped that in the near future the tank gunner will be able to have all around vision, at the same time being entirely protected against enemy fire.



Improved semi-automatic rifle under development at Springfield Armory

Developments in Small Arms

By

J. C. GRAY

Member A. O. A.

THE rifled musket has been in use for only a short period, as compared to the many centuries during which armies have existed and nations have engaged in warfare. In this short time, however, the rifle itself has undergone many changes, and since the perfection of the metallic cartridge we have seen a very considerable development of the original idea; including refinements of sighting, improvements in ballistic characteristics, the production of smokeless powder, the perfection of the machine gun, the automatic pistol, and so on; each year adding something new.

Touching on only the more outstanding items in which new developments are to be expected, it may be said that indications now point to the possibility of perfecting a self-functioning shoulder rifle, a light machine rifle capable of delivering accurate sustained fire for short periods, and a long-range, hard-hitting ammunition for machine guns and rifles. There is also approaching completion a .50 caliber machine gun which it is expected will be a distinct advance step in this type of weapon.

Hand arms are, in general, fairly well standardized, not only in the United States, but throughout the armies of the world. Experience gained during the war points to the possibility of eliminating the saber. The trench knife, while valuable as an auxiliary weapon under conditions of stabilized warfare, is a special purpose arm, the use of which will no doubt be limited. In the automatic pistol, as at present issued, there is little room for improvement, if reports from the troops using it are to be relied on, and no changes are thought probable at this time. On the whole, it may be said that no radical improvements in hand arms appear to be necessary.

The shoulder rifle is the principal weapon, in point of numbers, of all the various types in use. The infantry of all armies is armed with the rifle, and it is the infantry which in battle is called upon to bear the brunt of the fight.

The importance of having a well-designed and properly made arm of this type is very great, and as a consequence, constant attempts are being made to improve it. In our service arm, commonly known as the "Springfield," we are as well, and perhaps better, equipped than any other nation.

However, continued efforts have been made to obtain a self-loading rifle to replace the hand-operated arm, not only in this country, but abroad. It seems to be the general opinion that the last word in small arms will only be said when this result is accomplished. For a number of years, the Ordnance Department has held trials of guns of this type which have been submitted for test. Up to the present, and considering arms of foreign make as well as those from our own country, complete success has not been attained. It is not particularly hard to make an auto-loading rifle, provided the questions of weight or the characteristics of the ammunition to be used are not considered. The light Browning, for example, could be modified so as to make it semi-automatic only and there are several reliable self-loading sporting rifles on the market. It is only when an attempt is made to reduce the weight of the weapon and at the same time to provide for the use of a cartridge of high intensity, such as our present standard, that trouble is encountered, and it is this which has rendered the problem so difficult to solve.

A maximum weight of ten pounds has been set as the limit within which the rifle must be made in order to be sufficiently light for use as a weapon for general infantry armament. Trials are to be held during the latter part of this year, and it is hoped that the results will be successful. There will be published shortly a specification which will include data covering the results desired, and emphasis will be placed on the fact that a cartridge of good military characteristics may be used, even though it be somewhat smaller than the present standard.

It seems pertinent here to refer to the increasing tendency to the use of machine-gun fire at long ranges and the consequent necessity for providing ammunition suitable to the work to be done. This increasing use of machine-gun fire, it is believed, has greatly reduced the necessity for rifle fire at ranges approximating seven hundred yards, or over, and the auto-loading rifle problem would be considerably simplified if infantry rifle fire were only needed within ranges up to seven hundred yards. Thus two types of cartridges might be designed, one of high intensity and long ranging power for machine-gun use, the other of less intensity for use in rifles only.

Experimental data is available to show that should it prove impracticable to get a weapon of the auto-loading type suitable to the service cartridge as now used, one can be obtained which will be no less accurate than our present arm at infantry ranges, using ammunition giving practically the same height of trajectory and danger space up to eight hundred and possibly one thousand yards, and with the advantage of using a cartridge materially lighter, thus increasing the carrying capacity of the individual soldier.

Experience gained with the Model 1917 Rifle, which is provided with a receiver sight, has demonstrated the advantage of this type. Studies have been made looking to the incorporation of this feature in the Springfield, and numerous sights have been submitted and tested. It is yet too soon to make other than a general statement, but it appears very probable that eventually a receiver sight for the Springfield will be obtained that will still further improve this arm.

The evolution of the shotgun as a weapon for military purposes is believed to be complete, and it is not expected that any improvements which may possibly be forthcoming will affect its use in warfare. From the best data available, it appears that a very small number of shotguns were actually issued to front-line troops during the war. However, while the weapon was found to be adapted to certain purposes, its rather complicated mechanism and specialized usefulness were considered a bar to its extended issue.

Taking up as next in order the group which includes the various self-functioning weapons, the automatic rifle may be regarded as unique. No army other than our own has a weapon of a type exactly similar to the light Browning. Originally, this arm was intended as an auxiliary weapon for infantry, of such weight as to be easily carried, and for the purpose of providing increased fire power. While no fault can be found with the gun from a mechanical standpoint, it has been found to be too heavy for efficient shoulder use by the soldier of average physique and not well adapted to delivering standard bursts of fire.

Should a place be found in the service for a machine rifle, particularly by cavalry, it is expected that an evolution may occur in which the Browning automatic will be changed by the addition of a heavier barrel, a bipod, and a magazine of greater capacity, to provide a weapon of this type which will have superior qualifications.

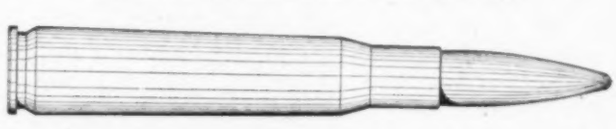
It is the machine gun, capable of long-sustained, accurate fire, which has proven to be of the greatest interest to both the designer and user of small arms. The enormous use of this type of weapon was one of the outstanding developments in this line during the war. The Browning, now issued, has proven very satisfactory; in fact, fundamentally this mechanism is so good that little, if any, change is expected for a considerable period of years.

The adoption of the machine gun for use in airplanes has, however, made necessary a series of studies looking to the improvement of the mechanism for that use by changing the feed box so that cartridges may be inserted either from the right or left side, thus permitting the guns to be used in pairs, and by further modifying the gun to allow the highest rate of fire.

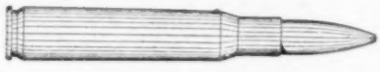
In the method of mounting machine guns, however, improvements may be expected. The tripods which have been developed have not been as fully satisfactory as was hoped, and studies have been under way for some time with a view to the improvement of both the ground and anti-aircraft types. It is rather early to predict complete accomplishment of the desired results, but certainly we may look forward to something new.

What has been said concerning the efficiency of the machine gun is not so true when the ammunition is considered. Experiments with foreign material have conclusively demonstrated that in the matter of range our present cartridge is inferior. An attempt has been made to remedy this condition, and the development of a boat-tailed bullet, adapted for use in the .30 caliber machine-gun cartridge has resulted. The new bullet has not been definitely recommended for adoption, but indications point to the possibility of perfecting a .30-caliber ammunition capable of delivering effective fire at ranges up to thirty-five hundred and possibly four thousand yards. It is here noted that experimental

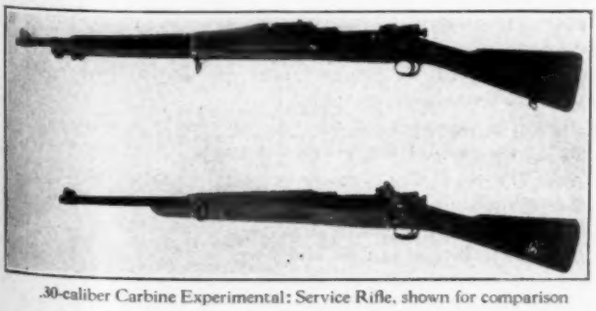
The new .50-caliber Browning Machine Gun, ground type



CAL. .50 CARTRIDGE



CAL. .30 CARTRIDGE



.30-caliber Carbine Experimental: Service Rifle, shown for comparison

Experimental Browning Machine Gun, with Bipod

data already obtained indicates that the tapered base does not begin to be effective until the projectile is traveling at a rate approximating the velocity of sound. For use in the shoulder rifle, at ranges up to one thousand yards, there is practically no advantage in the boat-tailed bullet over that having a flat base.

Tanks and armored airplanes used in war have resulted in an attempt to provide adequate means of offense and defense. A development program is under way as the result of which it is expected to obtain a weapon somewhat similar to the Browning, but of .50 caliber, firing a bullet approximating 800 grains in weight, and with good armor-piercing qualifications. The pilot-ground type gun is completed and has been given a number of tests. So far, indications point to very good results, with adequate ranging and ample speed of fire. The problem of designing this gun for anti-aircraft, tank and aircraft use has been finished and the pilot guns are well along toward completion.

In addition to the foregoing, experiments are being carried on with a gun of 37 mm. caliber, firing a projectile of about one pound in weight, which functions automatically and is designed primarily for aircraft use. It is too early in the development stage to predict accurately just what may be expected from this gun, but should it be successful we will have an exceedingly powerful weapon with a wide range of usefulness.

The scope of this article has been limited to cover the more outstanding developments. To have covered all the experimental programs under way in small arms alone, taking up each item in detail, would have filled a small-sized volume.

In conclusion, it may be said that the outstanding new departure of perhaps greatest importance is the promise of a really usable self-loading shoulder rifle. The effectiveness of the individual soldier is of greater importance than ever before. It is necessary that he be able to move quickly and that he have initiative and resourcefulness in a high degree. Arms for the individual must be designed with these principles in mind.

Competitive Test of Semi-Automatic Shoulder Rifles

September 15, 1921

The War Department is interested in securing a satisfactory developed semi-automatic shoulder rifle. The general requirements of such an arm are as follows:

The rifle must be of a self-loading type, adapted to function with cartridges not less than .25 caliber or greater than .30 caliber, of good military characteristics, and preferably to fire the U. S. cartridge, caliber .30, model 1906. It must be simple and rugged in construction and easy of manufacture. It should require but little more attention than the regular service rifle when placed in the hands of the average soldier.

It is planned that competitive tests of arms of this character will be held about September 15, 1921. The War Department will be pleased, however, to receive and subject to preliminary examination and test such rifles as inventors may care to submit prior to competitive trials. Persons having semi-automatic rifles which they desire to submit for preliminary trial should address the application for such test to the Chief of Ordnance, United States Army, Washington, D. C.

For the guidance of inventors in perfecting a design of the type the following information regarding characteristics is furnished:

The following features are considered necessary:

(*a*) The rifle must be simple, strong, and compact. Weights should be well balanced and so placed that the essential strength is given to components requiring it. Ease of manufacture should be a guiding factor in preparing a design.

(*b*) The mechanism must be well protected from the entrance of sand, rain, or dirt, and should not be liable to derangements due to accidents, long wear and tear, exposure to dampness, sand, etc.

(*c*) Components of the mechanism should be the fewest possible, consistent with ease of manufacture and the proper functioning of the weapon. Parts requiring constant cleaning or which may require replacement should be designed with a view to ease of dismounting by the use of not more than one small tool, preferably the service cartridge.

(*d*) The rifle must be so designed that the magazine while in position in the rifle may be fed from clips. The magazine may be detachable, but this is not considered desirable. The breech mechanism must be so designed as to preclude the possibility of injury to the firer due to premature unlocking. It is preferable that the bolt or block be positively locked to the barrel at the moment of firing. The capacity of the magazine should not exceed ten rounds.

(*e*) The firing mechanism should be so designed that the firing pin is controlled by the trigger and sear direct; that is, the bolt mechanism should move forward to the locking or firing position with the firing pin under the control of the trigger and sear mechanism, so that the cartridge is not ignited until the trigger is pulled to release the firing pin. The bolt, or block, should remain open when the last cartridge in the magazine has been fired. In case a detachable magazine is used the insertion of a new magazine should not release the bolt.

(*f*) The trigger pull, measured at the middle point of the bow of the trigger, should be not less than 3 or more than 5 pounds. The trigger action should be similar to that of the present service rifle, *i. e.*, it should have a light first pull, after which there should be no appreciable backward motion until the sear is released.

(*g*) An efficient safety or locking device must be provided, permitting the rifle to be carried cocked and with cartridge in chamber without danger. The rifle should remain cocked and ready for firing when the safety device is unlocked.

(*h*) The weight of the rifle, with magazine empty and without bayonet, should be a minimum consistent with proper functioning, and in no case should exceed 10 pounds.

(*i*) The rifle must be so designed as to give good balance and be adapted to shoulder firing. The general appearance and outline of the gun should be, as nearly as practicable, the same as the United States rifle, model 1903.

(*j*) The rifle is to be strictly semi-automatic; that is, a self-loading type, and is not to function as an automatic rifle. The trigger mechanism should be so designed that it will be impossible to fire more than one shot with each pull of the trigger; the trigger must be released and pulled again for each successive shot.

(*k*) The accuracy of the rifle should be comparable to that of the present service shoulder rifle.

(*l*) The stock should be so designed, if practicable, as to allow ventilation of the gun without charring or overheating the wood, and it would be desirable that an inner lining be provided to insure against charring.

(Continued on Page 281)

Long Range Small Arms Firing

PART II

The Determination of Ballistic Data by Actual Firing

By

GLENN P. WILHELM
Member A. O. A.

[*Note.*—The establishment of small-arms experimental ranges at Borden Brook, Mass., and at Miami and Daytona, Fla., has been discussed in Part I of the present series on Long Range Small Arms Firing, published in the January-February number of ARMY ORDNANCE. Part I was a general article describing the causes leading to the establishment of experimental ranges, including a description of each station and also showing some of the information and results obtained. Part II will be confined mainly to a description of the principal methods used to obtain the data, and showing not merely how the results were obtained, but a'so their probable accuracy.
The remaining articles will be on special subjects, confined to one or more important phases of the experiments. For this reason the methods described in the present article will not necessarily include the methods of determining data which will be later more fully described under the special subjects. The remaining articles will, however, in the main consist of results rather than methods. While each article of the series is complete in itself and can be read independently of either the preceding article or the articles to follow, yet at the same time it is advisable to refer to the other articles of the series for a better understanding of the whole subject. Particularly is this true with regard to the photographs, which as a general rule will pertain to the entire series and not merely to one article.—ED.]

THE discovery of the planet Neptune has been regarded as the greatest triumph of mathematical astronomy. Uranus, which up to the year 1846 had been known as the most distant planet, was gradually getting off the beaten track which computations showed it should follow. However, the distance difference between its observed place and the path prescribed for it was only about two minutes of arc.

Minute as this discrepancy was (a silver dollar at a distance of 150 yards subtends an angle of two minutes), it was sufficient to enable the position of a hitherto unknown planet, viz, Neptune, to be determined by computation. Two mathematicians, Leverrier, of Paris, and Adams, of Cambridge, England, independently worked out the mathematical operations, and by considerably different mathematical methods reached the same solution, which enabled a practical astronomer provided with the necessary apparatus to actually locate the disturbing planet by observation.

However, wonderful as this mathematical achievement is, it is marred by an unfortunate error which occurred in the computations of both men. In addition to determining the planet's position in the sky, they also had calculated the elements of its orbit and a value for its mass, which were very greatly in error. The reason for this error is that they had *assumed* that the mean distance of the new planet from the sun would follow "Bode's Law," an assumption which is not even approximately true.

Their supposition, however, was justified by the available data at that time, since all the other planets, including Uranus, followed "Bode's Law" very closely. Nevertheless the computed elements were so much in error that several authorities have contended that the discovery of Neptune was a "happy accident."

Fig. 1. Parallel beaten zones from four Brownings; range, one-half mile

Another conspicuous example of the wonders of mathematics is in its application to the determination of the path which a bullet travels through the air. Mathematics is an exact science which is sometimes erroneously held to be infallible and capable of unlimited application without regard to facts. In the case of the planet Uranus, mathematics was able to determine the cause and location of the disturbing factor only after observation had shown that something was affecting the planet. As soon as mathematics proceeded to go beyond the facts and became based upon an assumption it no longer was infallible, and great errors resulted.

This is analogous to the application of mathematics to the flight of bullets, which, as long as it is based upon observation and experiment, is absolutely reliable, but when observation and experiment fail, and it becomes based upon assumption, great errors creep in.

Some enthusiasts of no mean mathematical ability let their confidence get the better of their judgment and proceed on a policy which might be stated as follows: "When an experiment disagrees with mathematics, repeat the experiment until it does agree." Of course, there are experiments and experiments, and it is probably almost as easy to err in performing the experiment as it is in the computation due to unavoidable errors and unknown variations.

The experimental firings, upon which ballistic tables up to the time of the Great War were based, were performed by Krupp at Meppen in 1881. Mayevski determined the laws of air resistance from the Krupp firings, these laws being extended at a later date. In our own country the computations of Mayevski and others were converted into English units by Colonel Ingalls.

The first artillery tables used by the United States Army were computed by Colonel Ingalls from the work of Bash-

forth in England, Bashforth having used the data obtained by experiments in England on projectiles which are no longer in use.

Bashforth's spherical and round-nosed projectiles were superceded by Mayevski's short, ogival projectiles, which, in turn, are now being replaced by long, pointed and boat-tailed projectiles. Inasmuch as it was necessary to replace the original tables based on Bashforth's coefficients by tables made up by Mayevski, it is not strange that the great number of experiments performed during the Great War proved that Mayevski's formulæ are inadequate and that new tables are necessary. Such, in brief, is the present probable status of exterior ballistics among all armies.

Until the Great War, and even during the war, practically all fire-control tables for both artillery and small arms were based upon the original computations of Mayevski. In most countries fire-control tables for small-arms ammunition were made up entirely by computation based upon the determination of certain experimental data at short range.

The amount of experimental data available for small arms at ranges beyond about 1,000 yards has been extremely limited. Since it was difficult to determine experimental data with small arms beyond 1,000 yards, and since the flight of small-arms bullets at ranges up to 1,000 yards apparently conformed to the path of projectiles as laid down by Mayevski's formulæ, it was *assumed* that the flight of the bullet beyond 1,000 yards would also conform to the same laws. And just as the assumption in the computations in the orbit of Neptune caused a grievous error, so the assumption that the flight of the bullet at long range will follow the same laws as it does at short range has resulted in another serious error. This is due, not to an inherent error in mathematical science, but to erroneous assumptions of mathematicians.

The present article, therefore, will show how the data was obtained from long-range, small-arms firing, which, by the use of mathematics, will enable the Ordnance Department to formulate the necessary laws for precisely determining the path of the bullet at long range as well as at short range.

It is particularly intended to show with considerable detail the various methods used, inasmuch as ballistic calculations had been standardized up to the time of the Great War after extensive research, entailing the study of celebrated ballisticians; and unless the experiments which are about to be described involve the minimum of error it would be only reasonable to presume that the experiments were in error rather than the established methods.

In general the Borden Brook and Florida firings demonstrated that the application of Ingalls' tables to the computation of the path of small arms, flat-based bullets at long range is in serious error, in that the computed trajectory curve is far flatter than the actual trajectory; yet at the same time the same tables for a tapered base or boat-tailed bullet obtain a range which is entirely inadequate and a trajectory which is entirely too steep.

Ingalls' tables did not take into consideration the shape of the base of the projectile when determining the coefficient of form and the ballistic coefficient, although the present experiments will show that the difference in the performance of these two types of projectiles is very great at ranges beyond 1,000 yards for small arms.

Experimental Methods, Borden Brook Reservoir

The error usually made by persons unfamiliar with experimental firing is that valuable data can be obtained immediately by doing a limited amount of actual firing. However, to overthrow all previous ballistic data by checking that data by actual firing, requires extensive tests by a trained personnel with extremely accurate instruments over a considerable period of time.

The original Borden Brook experiments were for the purpose of determining by actual firing the following information for our .30-caliber service ammunition and likewise for various other types of small-arms ammunition:

Obtaining range for—
Angle of Elevation as corrected by Angle of Jump and Clinometer seat errors.
Deflection of Gun for purpose of measuring Wind Effect and Drift.
Time of Flight.
Angle of Fall.
Penetration.
Accuracy.
Machine Gun Dispersion—Vertical and Horizontal.
Barrel Life.

Considering that in securing the foregoing information, the data was chiefly to be obtained at ranges beyond 1,000 yards, the size of the task can be appreciated when it is realized that the securing of such information had never before been attempted.

As shown in the previous article, Borden Brook Reservoir is an open body of water surrounded by hills, giving sufficient elevation so that the surface of the water can be seen from short ranges up to ranges as great as about 2,600 meters.

Determination of Range

The method used at Borden Brook in obtaining the ranges was as follows: In general the principle of determining the range was to set the guns at a known vertical distance or height above the surface of the lake. An accurate angle measuring instrument was also set up near the guns at a known height above the surface of the lake. The guns were fired into the water, and the vertical angle of depression from the horizontal plane at the height of the instrument to the splash of the bullets in the lake was measured by the instrument. It follows, then, that to determine the inclined range from the height of the instrument to the center of impact in the water, the height of the instrument is divided by the sine of the angle of depression read on the transit. In order to get the horizontal range, the height of the instrument would be divided by the tangent of this angle. The instrument then becomes a depression-range finder.

There can be no question in regard to the accuracy of this method, providing that the work of determining the height of the instruments above the lake, and other instrumental work, was in the hands of competent engineers.

At Borden Brook Reservoir several positions for the guns and instruments were selected.

First Position. The first position was with the instrument mounted on a rock at a height of 65 meters above the lake. The guns were slightly in front of the instrument. This position is illustrated in Fig. 1. In this case the instrument illustrated is a Battery Commander's Telescope. The height that the cross-hairs on the instrument were above the level of the lake was determined by an accurate survey. The level of the lake was determined daily by readings to a tenth of a foot. The inclined range, as determined by the instrument, was corrected for the distance the guns were located in front of the instrument.

The illustration shows four guns firing automatically into the surface of the lake, the beaten zone of each gun being approximately the same range. The minimum range possible at this point was about 500 meters—the maximum

about 1,300 meters. The depression angle, as determined by the instrument for the minimum range was about 7° 28′, and for the maximum range the angle was about 2° 52′.

At the maximum range an error of 1 minute would give

Fig. 2. Mid-Range Firing, using Mann rest and transit to secure ballistic data

an error in the range of about 7 meters. At this location the range could be increased to 1,500 meters by going back 200 meters, giving a new height of instrument of about 90 meters. In this position, at the maximum range of 1,300 meters, an error of 1 minute would again be about 7 meters.

Second Position. Position No. 2 was at another portion of the lake, shown in Fig. 2, the height of instrument being about 95 above the surface of the lake. The minimum range was about 1,500 meters and the maximum about 2,000 meters. At this height of instrument an error of 1 minute at the maximum range would be about 11 meters.

Third Position. Position No. 3 was with the instrument located on the roof of a building. Two platforms were constructed on this roof—one upon which the instrument was set and the other one for the observer to stand upon while reading the instrument. In order that there would be absolutely no motion to the instrument while reading, the observer used a mirror for reflecting the bubble and reading the micrometer.

The height of instrument was about 110 meters above the lake. The minimum range at this point was 1,900 meters and the maximum less than 2,700 meters, depending upon the height of the lake. At 2,700 meters an error of 1 minute in reading the instrument would give a range error of about 20 meters.

The instruments used by the observers were:

One Battery Commander's Telescope, reading to 1 mil.
Six Standard Transits, reading to 1 minute.
One Gurley Hell Gate Transit, reading to 10 seconds of arc, both in elevation and deflection.

Method of Checking Ranges

The big problem at Borden Brook was the correct determination of the range, and to insure that the range data were absolutely reliable an elaborate system of checking was devised.

In addition to using instruments at the gun as depression range finders, transits separated by a horizontal base line of considerable length were also used on the flank of the guns. These base-line instruments were used to check the ranges obtained by the instruments at the gun from time to time, the majority of readings, however, being made at the gun.

The ranges as read by the instruments at the gun were also verified by means of floats which were set at a known range and by means of which it was possible to obtain by direct observation the range of a given burst.

Instrumental errors were constantly reduced to the minimum by reference to a topographical map of the reservoir and its vicinity, which enabled readings to be taken from time to time to bench marks of known measurements.

A great many of the tests were fired with observers located at or near the impact of the bullets, who, by means of floats, bench marks, etc., recorded the range independently of the ranges obtained by the instruments at the gun.

The maximum range errors possible were less than 1 per cent on individual readings, the average individual reading being much less. The probable range error, on account of the number of observations which were taken, was reduced still further by means of curves plotted from the observed data, each curve being located by a study of the number of points involved and considering the probable value which could be assigned to each point.

On account of the length of the ranges observed, which in a great majority of tests was never less than 1,000 meters, any discrepancies due to erroneously determining the range were of a minor nature.

Determination of Elevations and Deflections

Equally as important as the determination of range was the measurement of the angle of elevation and the horizontal angle of deflection of the guns. In some cases the elevation was determined by means of the rear sight, a careful measurement having been taken of the height of the front sight above the center line of bore and the height of the

Fig. 3. Short Range Firing Point, Borden Brook, showing angle of Fall Screens and Penetration Butt

various graduations of the rear sight above the center line of bore. By means of these dimensions, and the length of the sight radius, it becomes a comparatively simple calculation to determine the angle between the center line of bore and the line of sight for a given rear-sight reading.

In practice, it was usual to set the sight leaf at a given elevation and fire into the lake, observing the splash of impact. The center line of bore of the gun was raised or lowered until the line of sight coincided with the impact.

This is one of the simplest and most rapid methods which can be devised for targeting a gun, and so effective is it in practice that it has been suggested as a solution to the problem of the quick training of recruits in rifle fire, because the firer almost instantly sees where his bullet has gone and is able to correct his sights accordingly.

The usual method, however, of measuring elevations was by means of clinometers or quadrants, which were placed upon a suitable flat surface, known as the clinometer seat especially provided for on the various types of guns. The clinometers which were used for elevation measurements were generally of the service machine-gun clinometer type. For purposes of more precise measurement and for checking the results, a special clinometer was used which was graduated to a least reading of 1 minute of arc.

The deflection, or direction, of the original flight of the bullet was obtained either by means of a windage scale on the rear sight or by means of a graduated dial on the mount or tripod which held the gun.

The zero of this scale or dial coincided with the zero in azimuth of the range transits, so that if the bullet deviated neither to the right or left, the splash as seen in the water would be in direct prolongation of the center line of bore. The difference between the direction dial reading on the gun and the transit azimuth reading on the splash is, of course, the total lateral deviation of the bullet due to all causes.

All elevation measurements were corrected for the following errors:

First, the angle of jump, which was determined by first bore sighting the gun for the purpose of determining the center line of bore, and firing the gun; then measuring the distance between the center of impact of the shots and the intersection of the center line of bore on a vertical paper screen at a known distance, making due allowance for the sighting error and the drop of the bullet.

Second, the error in the clinometer seat, which was determined by finding the angular difference between the clinometer seat and the center line of bore. This was obtained by inserting a bore level in the barrel and placing a clinometer on the clinometer seat, and taking the readings when the center line of bore was shown to be horizontal.

All clinometers used in measuring elevations were properly zeroed, so that when the clinometer reading was zero the level bubble was in the center of its tube.

All elevations measured by clinometer were, of course, corrected by the negative angle of site introduced by the necessity for inclined firing.

Deflection measurements were also corrected by changing the readings of the direction dial on the mount or gun an amount equal to the lateral angle of jump.

Time of Flight, Angle of Fall, Penetration

The total time of flight for all ranges was obtained by firing single shots at the same time that a test was being held for the purpose of securing elevation and wind effect data. The time of flight was secured by means of a modified form of the Aberdeen Chronograph, which consists of a slowly rotating drum kept at a very constant speed by means of an electric motor. The measurements were made by experienced observers operating a telegraph key by visual observation of the flash of the gun and the splash of the bullet. At short ranges such a method is not reliable, due to the shortness of the time of flight. At long range an experienced observer can keep his observations well within the precision required by the nature of the other factors entering into the experiment.

Measurements of angle of fall were made at long range by means of paper screens. Such an arrangement is shown in Figure 3, in which two paper screens are shown on the narrow point of land extending out into the lake, which were being fired at from the left flank. These determinations of the angle of fall were not very satisfactory, due to the fact that a paper screen of sufficient thickness to withstand the wind appreciably affects the flight of the light small-arms bullet on the descending branch of its trajectory at long range. Some angles of fall were measured by the marks of the bullets in penetration butts and in earth.

Long-range penetration was obtained by means of a penetration butt made up of 1-inch pine boards placed 1 inch apart, and located in a convenient position so as to allow ranging the shots of a machine gun burst into the penetration butt, which otherwise could not be hit.

Such a butt is shown in Figure 3 at the very tip of the narrow point of land extending into the water. This penetration butt was only 3 feet square, which at a range of 2,400 meters is absolutely invisible; yet by the method outlined it was possible to shoot over a score of shots into the butt out of several machine-gun bursts.

Wind Effect of Drift

As has already been shown, the total lateral movement of the bullet in flight was obtained by means of the angular difference between the direction of its initial flight and its impact in the water. By obtaining this record at all ranges under various kinds of weather conditions from a large number of tests enough data would be obtained to formulate new tables of the effect of wind and drift on small-arms bullets at long range. No attempt was made at Borden Brook to separate the lateral movement of the bullet due to drift from that due to wind.

The determination of accuracy of small arms and ammunition at Borden Brook was confined to comparative long-range dispersion, for which purpose the data was plotted into curves.

Machine-gun Dispersion

Machine-gun dispersion was obtained at all ranges by means of observations of the length and width of the beaten zone on the surface of the water. From these measurements calculations were made involving the angle of site and the range, transferring the measurements on the horizontal surface of the lake into the probable length and width of dispersion on a surface parallel to the line of site.

The result would be the same as if the guns were at the same elevation as the surface of the water.

From these calculations the vertical height and width of machine-gun dispersion were obtained.

Barrel Life

The accuracy of machine-gun barrels, when fired under service conditions, was accurately obtained by plotting the dispersion obtained upon the surface of the water. This method was admirably suited to the purpose, as the data shows very clearly the point at which the machine-gun dispersion increases rapidly. Visual observations and photography also show the same results.

Daily records were kept of the meteorological conditions under which the various tests were conducted. By means of anemometers placed at periodic distances along the line of fire, readings were taken of the velocity and direction of the wind. Readings were also made of the temperature and barometric and hygrometric conditions.

Proposed Form of Standardized Government War Contract

Not Standardization but Abolition of War Contracts

By

James A. Drain

Member A. O. A.

IT seems to me well worth while to consider whether the enlightening discussion by highly qualified commentators on the Standardization of War Contracts previously published in ARMY ORDNANCE is not a waste of ammunition because, though good ammunition, fired at the wrong target. Previous articles, for the most part, presume a continuance of the conditions obtaining in the last war. Let us look into the question for our Nation's sake if not for our own. For that purpose I submit not a brief but a discussion of principles.

One of the functions of government is to conduct war. By the Constitution of the United States the war-making power is exclusively vested in the Federal Government. An equally important function of Government is to conserve the rights of all citizens as to person and property under every condition. In peace we have one set of conditions, in war another, 180 degrees separated.

A passage from a late book by John Hays Hammond and Jeremiah W. Jenks says:

> Democracy is not the expression of the equality of all men, but of their equal right to develop, to exercise, and to profit by their individual qualities; and that no program of social justice can ever realize its object if it seeks to interpret equal opportunity in terms of an equal reward for unequal service.

Of course, this observation relates to normal times, peace times, when, according to the whole experience of the world from the first history of mankind up to this very minute, all efforts to organize society without the competitive element have failed. In war we face different factors: the competition highly intensified and sanguinary is between an enemy nation and our own. Our causes as citizens of one nation are one.

Love for men of other nations felt in peace becomes in war close to hate. But it isn't necessary to dilate upon these points to those who will read this. You all understand what war is as a disturber of peace-time individual rights and international harmony.

Granting, then, that we must, in war, set aside, suspend or subordinate the rights of the individual to those of the nation, we may take it as a fundamental, may we not, that the duty of the nation to its citizens and of citizens to the nation involve the utilization of every available resource, spiritual, intellectual and physical, to successfully prosecute any war into which the nation may be forced. And, assuredly, the United States will have to be forced into any war in which it engages; forced either by the attacks of an adversary or the unbearable conduct of some international malefactor.

Did we, during the last war, of which our memory is still so vivid, make use of the full power of the nation, a power which all good citizens desired it to exercise, to utilize all available resources of the nation to win the war? Assuredly not.

What are the facts? We drafted man power to fight. It was right that we should. But no one needs to be told that in drafting men to fight we made a requisition upon the most valuable possession of our citizens, and we took or prepared to take from them the one thing which we could not restore to them, namely, life. True, any citizen fit to live under the Flag is willing to die for his country, and our citizens showed that willingness. They accepted a draft law because it bore, in the main, equally upon all of them.

Did our other efforts to utilize our resources result in an equal distribution of burden? Not by any means. Provision of law was made for taking over facilities for the manufacture of war material. It was done, not generally, but to a considerable extent. Price fixing was practiced, not as to all items, but as to many, and the railroads were commandeered. There was no direct drafting of capital or labor, though those with capital and those classed as labor did largely voluntarily assume burdens by buying Liberty Bonds, subscribing to Red Cross drives and in other useful ways help to win the war.

No one can deny that we had profiteers in considerable numbers among us: capitalists, laborers, farmers, shopkeepers, who took all they could and gave as little as they dared. That is human nature at its worst. In war you expect men to be less selfish. In general, that is true, and as to the United States in this war it was true of the majority.

Voluntary contribution to extensive war efforts is just as inefficient as raising an army by voluntary enlistment, and we know that is the height of inefficiency.

There is a rather widespread popular impression that the business men of this country who made contracts with the Government to furnish it war material are to be classed, by reason of that fact and without further inquiry, as profiteers. The truth is exactly the reverse.

The majority of those owning plants, mines, and other facilities which manufactured or supplied war material would have done better could they have escaped the war obligation, or closed down altogether for the war. The discussion by others preceding this has been valueless if it has not shown clearly that the manufacturer who entered into a contract with the Government was actually placing himself practically without reserve at the mercy of the contracting officer.

It is only the narrowest statement of justice to say that while many manufacturers expected profit when they made contracts, this was a mistake. They realized before they made contracts, this was a mistake. They realized before they had gone very far that they could not make money and still carry out the wishes of the Government and help win the war; hence, their problem came to be one of limiting losses. To their credit be it said that in almost

every case, as between doing what the Government wished and doing what would be of most or any profit to them, they did the best they could to help win the war.

The participation of our men in the draft; the service of citizens in a thousand ways; the outpouring of money for Liberty Loans, the Red Cross and other drives were colossal. It showed the spirit of the people was right. Here a great waterfall pouring its millions of potential horsepower upon a few little over-shot wheels dabbling in the edges of the flow, while with proper installation all of this mighty energy could have been used.

If we can draft the man power of the nation to fight, and the people will stand for it, is it not reasonable to suppose that we can draft every other resource of the nation, and that the people will be glad to have that done? If a war is popular, it can be done. If a war is not popular, it should not be waged because it may be lost. A system of this kind would tend to prevent entry into war and guarantee success when entered.

You may quite naturally ask how this is to be accomplished. Of a surety it means changed laws. It will not be a very hard task to draft appropriate laws once we agree upon principles. There may be some difficulty in selling these principles to the people, but no insurmountable ones. The passage of the laws would be a simple task when we have agreed what they should be and convinced the country of the need for them.

Let us say that we agree, then, that a means should be found by which the total resources of the nation should be aggregated for war; a maximum of power; a maximum of effort; and a minimum disturbance of individual rights.

This means drawing a distinct line of cleavage between peace and war conditions; the freezing of prices the instant war is declared; the adjustment of many inequalities of that freezing process and all other possible questions during the war itself by tribunals specially constituted for the purpose; the drafting of the man power of the nation to fight and to work, of its capital and all facilities, industrial, agricultural and otherwise, upon such terms and under such conditions as to secure to every individual an opportunity to help to the fullest extent; to make the burden rest as nearly as may be with equal weight upon all; and to guarantee that no individual shall be the gainer in a material way by giving such help. In spiritual growth, in deserved recognition by his fellow citizens of his efforts, of gain to his nation through his aid, a citizen should profit, but in no other way.

Our men drafted to fight should be protected by a definite sum due to their heirs or beneficiaries for death and stated disability allowances, all immediately payable upon proof of death or disability; those damaged only in civil status by draft service to be protected by employment after discharge, if need be on public works, until they can fall into step with unmilitary life. As to property or facilities drafted, the return of it or its equivalent to owners without profit but without loss; in short, to such extent as is within the compass of the Government to return the country and all within it to the condition of before the war, with the pride of victory as part balance for its losses.

The editor will say that I have written long enough, but he will be wrong unless what has been said here shall convince you that these principles are sound, and that ways must be found to make them the active governing principles of our next war. If they are to be made so we must take practical steps at the earliest possible moment to insure that end, for war comes "like a thief in the night" and no man may say when it will be again upon us.

If you ask me what is the first step, I should say, upon whatever initiative you like, to have a special conference called of men from Congress, the War and Navy Departments, the National Guard, financiers, farmers, labor unions and representative women. Women, because they will play a much larger part in the next war than they did in the last, and in the last efforts were many and of great value in all of the countries engaged. Of course, some one will have to make a start and formulate a program. The *Army Ordnance Association* may well be that some one.

If, on the other hand, none of this argument seems sound and members of the Army Ordnance Association feel that we must go forward with the former incomplete, inefficient and grossly unjust method of waging war practically unchanged, then, there should, in my opinion, be a conference of officers of the Ordnance Department of the Army; officers who came to the Ordnance Department during the war from industry, and manufacturers, with a view to laying down the best half-way method. As an essential, to me a vital one, if we cling to the faulty past practice, would be provision in all contracts for the determination of disputed questions through some other agency than the contracting officer. If Uncle Sam is to contract with his citizens, he must not continue in the arrogant tyrannical way of ancient autocratic sovereigns to insist upon requiring of the other party to the contract things which he will himself not do, nor should he expect to be sole judge of close questions of performance. This is in no sense to be taken as a criticism of contracting officers of the Ordnance Department or any other department of the Government. In spite of an unjust and vicious system, through sheer inherent fairness and honesty these men have usually accomplished substantial justice.

But I cannot believe that we Americans, pioneers, who have shown ourselves so well able to carve ways through the physical, spiritual and political wildernesses of a new world need fear to plan and make a way by which with justice to all our citizens we shall in our next war utilize our every available resource to win that war. That means pledging not only "our lives, our fortunes and our sacred honor" to the support of the Government, but sound and wise provision of law proposed and passed in the coolness of peace for use in the heat of war, placing all of that we have and all that we are at the disposition of the country.

But finally and positively, I maintain that if you can draft men to fight in war, you can, and in all fairness and efficiency should, draft the total resources of the nation in war. If you agree with me, let us see that it is done.

[Certain features of the form of contract discussed in Major Gallaher's article appearing in the November-December, 1920, number of ARMY ORDNANCE have recently been incorporated in a new form of contract intended for peace-time requirements. This revision (Form 700), revised December 22, 1920, will be used in the Ordnance Office and at the arsenals in current contracts. The new form will be much briefer than the form which has been used. The verbosity of the old form is illustrated when comparison is made of one clause, which, in the old form, contained 1,151 words. The new clause contains 335 words.

The subject of Contract Standardization in the War Department has been under discussion in the War Department Technical Committee, of which Lt. Col. George M. Gibbs, G. S., is Chairman, and on which Col. David M. King is Ordnance Member. The sub-committee on contract forms, under the Chairmanship of Maj. Richard H. Hawkins, Ordnance Department, is engaged in a survey of recommendations, or requirements, of general application in the several supply branches of the War Department.—ED.]

"One Fifty-Five" vs. "Cent Cinquante-Cinq"

A comparative study of American and French Corps Artillery

By

T. A. CONLON
Member A. O. A.

THE 155 mm. gun carriage, Model of 1918 (Grande Puissance Filloux) is universally conceded to be the best design of Army Corps Artillery developed and brought forth during the war. Its simplicity in design, its wide angle of traverse (60 degrees), its compact and efficient recoil mechanism, its long range and ability to withstand hard usage, together with its graceful appearance, won for it ready approval from all those in a position to appreciate it.

Yet, before the war was brought to a close, the artillerymen found much to be desired in this carriage, and in the report of the Westervelt Board there are found specifications for a Corps gun and howitzer carriage that must not only possess the desirable features of the Filloux carriage but in addition thereto must have a greatly increased angle of elevation and range. Furthermore, this increased elevation and range must be obtained without exceeding the weight of the Filloux carriage. The depth of the pit dug to permit recoil of the piece when firing must be reduced or if possible, eliminated, in order that the time consumed in preparing the carriage for action may be reduced to a minimum.

In accordance with these specifications, the model of 1920 carriage has been designed to mount, with slight modifications, either the 155 mm. gun model of 1920 (built up), the 155 mm. gun model of 1920 MI (wire wrapped), the 8-inch howitzer model of 1920 (built up) or the 8-inch howitzer model of 1920 MI (wire wrapped).

The recoil mechanism is of the Filloux type; it differs from that used on the G. P. F. carriage in the greater area required in the recoil and counter recoil cylinders.

The elevating mechanism is entirely unlike that used with the French Carriage, which consists of a pair of helical gears at the end of the handwheel shaft, a pair of bevel gears at the end of the worm shaft and a worm engaging a worm wheel segment bolted to the under side of the cradle yielding a range of elevation from 0 degrees to 35 degrees—one turn of the handwheel representing 8.5 mils of elevation. On the other hand, the elevating mechanism on the new American carriage consists of a pair of bevel gears at the end of the handwheel shaft, a worm and worm wheel. The worm wheel is keyed on the elevating pinion shaft; the elevating pinions engage the elevating ares. The ares have a free fit on the trunnions, extensions

The new American 155 mm. Gun outranges the French 155-mm. G. P. F. by nearly five miles

on the side of the cradle give the firing load to the arcs The cradle is locked to the arc by the quick return mechanism. The range of elevation is 0 to 65 degrees; one turn of the handwheel represents 5 mils of elevation. The left arc forms a support for the sight bracket while the right arc forms a support for the gears of the quick return mechanism.

The quick return mechanism is a necessary addition to this carriage if rapidity of fire is to be obtained in view of the high angle of elevation and the slow movement through the elevating mechanism. The quick return mechanism is located on the right side of the carriage, rear. It is operated by one man who unlocks the cradle from the elevating arc and through the train of gears on the elevating arc brings the cradle to the loading stop (11 degrees). This stop is readily tripped if a lower angle than 11 degrees is desired for firing. In unlocking the cradle, the operator automatically locks the breech firing mechanism. The sighting is undisturbed by this loading operation and the sight and elevating mechanism are free to permit a new setting if desired. The cradle, after the piece is loaded and brought down by the train of gears mentioned above, automatically locks itself to the elevating arc, at the same time unlocking the breech firing mechanism.

The new carriage is provided with a spring equilibrator mounted on the top carriage and connected to the cradle through the trunnions to permit the recoil of the piece at a high angle of fire without digging too deep a pit. The equilibrator accomplishes this by making it possible to move the center of gravity of the tipping parts a considerable distance in front of the trunnions; on this carriage this distance is thirty-seven inches. The weight of the tipping parts is thirteen thousand pounds. In order to make the equilibrator function satisfactorily it is necessary to employ a regulator that will cause the spring effort of the equilibrator to equal the moment effort of the tipping parts at all angles of elevation. With the 8-inch howitzer model of 1920 it is necessary to start digging at 40 degrees elevation. The maximum depth of pit required at 65 degrees elevation is 15 inches and the same is true of the 155 mm. gun model of 1920.

With the French carriage it is necessary to start digging at 20 degrees elevation and the maximum depth of pit required at 35 degrees elevation is 24 inches. Were it possible to fire this carriage at 65 degrees elevation, it would be necessary to dig a pit 59 inches deep, as the tipping parts are balanced at the trunnions.

The French carriages are supplied with two hydraulic jacks and a metal lifting beam; the purpose of these is to prepare the gun carriage for action; with the aid of these tools the carriage is lifted and the limber run out, the trails lowered and swung to the position prepared for them, the pivot pin inserted in the axle and the axle spring unshackled. Considerable objection was made to the amount of time required for this and to overcome these objections in the American carriage a pair of screw jacks are built in the axle for lifting the carriage and inserting the pivot pin and unshackling the axle spring; for maneuvering the trails two long handspikes are provided and a stand on which to rest the trails while the limber is being withdrawn.

The trails on the American carriage are similar to those on the French G. P. F. with the exception of a new design of traveling lock. The piece when traveling on the carriage is retracted by a winch which fits on the end of the trail. Stops are provided on the trail for the gun and howitzer transport wagon. The spade connection has been modified; the spade has a large stud on the float that enters the under side of the trail members.

A transport wagon is provided for carrying the piece, the purpose of which is to distribute the loads, thereby increasing the mobility of the materiel.

To remove the piece from the carriage, the trail members are brought together on the ground and locked. The transport wagon is backed up over the trail until it strikes the stops provided on the trail. A lifting mechanism on the wagon catches in the rear end of the trail. In lifting the trails the rear wheels of the wagon are also lifted free of the ground bringing the slides on the cradle in line with the slides on the transport wagon. The lifting mechanism virtually binds these two vehicles into one. A removable winch is used to pull the piece on and off the wagon. The winch is supported on the front end of the wagon in the first instance and on the front of the cradle in the other.

The carriage limber is similar in design to the G. P. F. carriage limber excepting that the body is made of one casting and that there are no removable parts. The wheels are each 300 lbs. lighter than those used on the G. P. F. carriage limber and are the same as the wheels used on the transport wagon for this materiel.

The following table shows comparatively the principal characteristics of the new American 155 mm. and 8-inch materiel, the French 155 mm. G. P. F. and the 8-inch howitzer carriage (British) Mark VII. This carriage was used extensively by the United States Army in France during the war.

COMPARATIVE TABLE

	Length in Calibers	Muzzle Velocity (Normal)	Muzzle Velocity (Super)	Maximum Range	Maximum Elev.	Normal Length of Recoil	Wt. of Cannon complete	Wt. of Matériel in firing position.	Wt. of Gun Carr. & Limber, complete	Wt. of Max. Load Traveling	Width of Tread	Wheel Base	Overall Length	Overall Width
		ft. sec.	ft. sec.	yds.	deg.	inch	lb.	lb.	lb.	lb.	inch	inch	inch	inch
155 mm. gun carriage, Mod. of 1918	38	2380		17,700	35	71-43	8800	25,900	29,400	25,400	88.5	177	344	105.2
155 mm. gun carriage, Mod. of 1920	45	2000	2800	26,000	65	60-24	9200	24,000	28,000	17,000 *	88.5	188	290 *	104
8-inch How. carriage, Mod. of 1920	25		1925	18,000	65	71-40	9000	24,000	27,800	16,800 *	88.5	188	290 *	104
8-inch How. carriage (British) Mark VII	18.5	1520		12,500	45	52-24	7700	20,000	22,600	22,600	88.	187	555	96

*Cannon on Transport Wagon.

Joint Meeting

Ordnance Section, American Society of Mechanical Engineers
and
Army Ordnance Association

Rock Island Arsenal, Illinois
May 27 and 28, 1921

The Secretary is in receipt of the following cordial invitation:

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS,
29 West Thirty-ninth Street,
New York, *March 16, 1921.*

THE SECRETARY, THE ARMY ORDNANCE ASSOCIATION,
Munsey Building, Washington, D. C.

My Dear Sir: The President and the Council of The American Society of Mechanical Engineers note with considerable gratification the informal arrangements made by the Ordnance Section of our Society for a joint gathering with your Association at the Rock Island Arsenal, May twenty-seventh and twenty-eighth, when our members are to be the guests of the Arsenal upon the invitation of the Chief of Ordnance of the United States.

The President and Council, upon the recommendation of our Committee on Meetings and Program, therefore cordially invite the Army Ordnance Association to participate, and hope that the co-operative undertaking will be an unqualified success.

Yours truly,
CALVIN W. RICE, *Secretary.*

The above invitation has been accepted with pleasure by the Army Ordnance Association. Members who desire to attend are informed that Maj. F. C. Bull, Chairman, Organization Committee, states that the present plans of the Ordnance Section, A. S. M. E., are to leave Chicago on the midnight train, Thursday, May 26, arriving at Rock Island, Illinois, on the morning of May 27. The forenoon will be spent in an inspection of the Arsenal. After lunch the professional meeting of the Ordnance Section will be held. Papers will be read and steps taken to effect a permanent organization of the Section. The next day will be spent at the Arsenal. An opportunity for golf on one of the best courses in the Middle West will be offered those who bring along their clubs.

Members of the Army Ordnance Association who intend to be present at this joint meeting should notify the Secretary at Room 410 Munsey Building, not later than May 15, 1921, in order that further information in regard to details of the meeting may be furnished them.

(Continued from Page 255)

The Aberdeen Proving Ground

special development work in small-arms ammunition was not apparent. We had a rifle and ammunition which, for the purposes for which they were developed, were second to none.

The developments of the world war were, however, what brought out the vital need for proving ground facilities where the various types of small arms ammunition, both standard and experimental, could be adequately tested.

When this range is in operation, it will be possible to determine by actual firing, in a minimum of time and with a maximum of accuracy, practically any problem in connection with small arms ballistics.

To get the fullest benefit from this range, it is hoped, in addition to solving any firing problems that may be presented by the Infantry to extend, to a limited extent, the use of the range to private manufacturers of small arms and small-arms ammunition. If suitable arrangements can be made, ballistics of any commercial type of gun or ammunition can be accurately determined. This will enable the Ordnance Department to keep in touch with all developments in small arms and will tend to effect a close co-operation between the Department and the manufacturers.

Individual riflemen throughout the country will be encouraged to take up with the Department questions in regard to the ballistics of small arms ammunition and an endeavor will be made to keep the public informed through the different journals of any new development work.

(Continued from Page 272)

Competitive Test of Semi-Automatic Shoulder Rifles

The following features are considered desirable:

(*a*) The rifle should be capable of being used as a hand-functioned arm in case the automatic feature is disabled. The bayonet should be so attached as not to interfere with the proper operation of the piece under any conditions that may normally be expected.

(*b*) The use of special high-grade material, highly specialized heat treatment, or special-grade machine work or finish in general should not be required.

(*c*) An excess of oil or grease or any other material not readily obtainable in the field should not be necessary to the proper functioning of the piece.

(*d*) The use of special tools for adjustment or dismounting or assembling should be reduced to the minimum.

The following features are considered preferable:

(*a*) Sights that are over the center of the bore and so firmly fixed as to avoid any possibility of variation in position due to constant firing or rough handling.

(*b*) The rear sight not less than 2½ inches and not more than 6 inches from the eye when using the weapon in the prone position. It should be graduated up to 1,500 yards and have a wind gauge.

(*c*) In case a sight embodying the above points is not devised by the designer, the rifle should be so constructed as to permit the installation of such a sight.

Announcement

We regret that in submitting to us the manuscript of his article, "The Gage Problem in Ordnance Manufacture," printed in the January-February number of ARMY ORDNANCE, the author, Maj. J. O. Johnson, inadvertently omitted a foot note giving credit for use of certain material embodied therein. Inasmuch as we had no knowledge that any of this material had ever before been published, the manuscript was printed by us as submitted, and for our unintentional breach of ethics in this matter, we hereby tender sincere apologies to all concerned.

The following foot-note should have appeared on page 192 of the January-February, 1921, number of ARMY ORDNANCE:

"The subject matter following this note has been largely taken from notes and memoranda compiled by Lt. Col. E. C. Peck when he was Chief of the Gage Section, Ordnance Office, and which were used as the basis of articles by Colonel Peck in the *American Machinist* and also in *Mechanical Engineering*. Other portions have been abstracted from the report of the operation of the Gage Section, of which Colonel Peck was in charge during the war.

"The author wishes only to bring together under one heading portions of these notes in order that they may be found in a convenient place for future reference in case of need."

ARMY ORDNANCE

VOL. I. MARCH-APRIL, 1921. NO. 5

QUALITY PRODUCTION

"Wars of the future are being won or lost in the Ordnance drafting rooms of to-day."

AS applied to the repetitive processes incident to the manufacture of bicycles, automobiles, typewriters, sewing machines, etc., we frequently hear of "quantity production." The annals of American Industry are replete with accounts of marvelous accomplishments in this direction. But few of these even mention, much less give proper credit to, those who have performed the non-spectacular preliminary drudgery incident to perfecting the first "type" article, from which innumerable replicas are mechanically produced. Yet the quality of the entire series is largely determined by the quality of the "pilot" piece.

As regards Ordnance, the present is a period of *quality* production, the perfection of improved types as a result of World War experience. Quantity production is, at present, unnecessary, due to our fortuitous accumulation of munitions incident to the World War. However, when war threatens, quantity production will be necessary, vitally necessary—and suitability for manufacture by quantity production methods must ever be kept in mind in developing new Ordnance. A given device may be considered highly effective by the Line, and therefore greatly to be desired, but unless it is susceptible of manufacture in adequate quantities within a reasonable time it can not be adopted as standard and must give way to a less effective device which can surely be produced when and as needed.

The preceding pages comprise the Ordnance Technical Staff Number of ARMY ORDNANCE and outline the mechanism whereby the desires of the combat forces are reconciled with production possibilities. If this administrative procedure seems unduly complicated, account must be taken of the fact that nations go to war largely on the basis of designs worked out in times of peace. The painstaking care used to effect a perfect 75-mm. shell—the time and money used now to refine its slightest detail, are wisely expended in preparation for the possible need to manufacture a billion dollars worth of this single item of Ordnance alone. Similarly, through the long list of thousands of separate and distinct articles comprised in the general terms "ordnance," designs and specifications under consideration to-day may in the near future be manufactured in limited quantities only, but emergency may dictate their production by millions, in some cases even by billions, in which event the funds and energy expended in *quality* production to-day will be amply justified by prompt and adequate *quantity* production when the future demands it.

On the Right Track

EVEN a casual reading of the leading article in this number inspires the conviction that the present *modus operandi* in effect between the designers and manufacturers of ordnance and those who may some day be called upon to use these implements of war in the crucial test of battle, will be productive of excellent results.

A consideration of the comments thereon by representative officers of the Line of the Army leads to the conclusion that one great good has already been accomplished—the combat troops have a sustaining confidence in the weapons with which they are supplied. The importance of this factor for building up morale can be sensed in recollecting the determining influence of the almost religious faith in their Seventy-Fives inculcated in the French Army—a confidence in the efficacy of their ordnance which vastly increased the effectiveness of weapons in nowise superior to those of their opponents.

With Science and Industry advising as to possibilities of production, and the Line intelligently establishing requirements for effective use, Ordnance is in a position to render its real service to American manhood—by providing superior mechanical devices which conserve the human element by affording greater protection, by increasing striking power, and by strengthening resolution in the face of a determined enemy.

As established by General Williams and administered by General Ruggles, the present system is providing the combat forces with a measure of superiority in mechanical equipment which may some day save countless American lives. Army ordnance is on the right track.

Sale of Arms and Equipment to Reserve Officers

The following regulations will govern the sale of arms and equipment to officers of the Officers' Reserve Corps:

Reserve officers on active duty, after proper identification, may purchase necessary uniforms, accouterments, and equipment at the same prices and under the same rules and regulations as govern the sales of such articles to officers of the Regular Army.

Reserve officers not on active duty, after proper identification, may purchase, in such quantities as would be required by them when called into active Federal service, and at such places as may be designated in orders or from sales stores or other points of supply in the department or corps area in which they reside, necessary uniforms, accouterments, and equipment at the same prices at which such articles are furnished to officers of the Regular Army. Such officers will make the purchases as follows:

a. Those who reside near or in the vicinity of a depot sales store or other point of supply will purchase the articles from such store or point of supply.

b. Those who do not reside near or in the vicinity of a depot sales store or other point of supply will submit written requests for all purchases to officers in charge of depot sales stores or other points of supply.

c. All requests for purchase must be accompanied by proper means of identification establishing the fact that the person making the request is an officer of the Officers' Reserve Corps. The officers making the request will certify therein that the articles are for his own personal use, and that application to purchase is made under paragraph 1174, Army Regulations, as amended. The request will list the articles desired, and will state what number of articles requested, if any, have been previously purchased from the United States Government; if such articles are to be shipped, the address will be stated. When articles are to be shipped, request will be accompanied by a money order or draft, and the amount will cover the cost of the articles and the necessary packing cost, but will not include the cost of transportation, as all such articles will be shipped by parcel post, express, or by freight collect. Money orders or drafts will be made payable as follows:

(1) For quartermaster property: To the "Officer in Charge of Depot Sales Store," or other supply point.

(2) For ordnance property: To the "Chief of Ordnance."

(3) For signal property: To the "Chief Signal Officer."

Officers in charge of sales stores, or other points of supply, will assure themselves that an individual making request to purchase is entitled to, and is only obtaining, the articles that would be immediately required by him when called into active Federal service.

With the exception of clothing and ammunition, sales of more than one article of equipment to an officer will not be made unless he can establish by suitable evidence the loss or destruction, through no fault of his own, of such article previously purchased by him. Supply bureaus will maintain records of all articles having serial numbers sold to reserve officers.

Reserve officers when called to active duty are not authorized to have issued to them on memorandum receipt for temporary use any article previously purchased by them.

Information concerning cost of articles, packing, etc., can be obtained by writing to the quartermaster of the department or corps area, or from officers in charge of depot sales stores or other supply points.

Memberships and Subscriptions

Due to the increasing number of orders from Public Libraries, Colleges, Technical Libraries of Corporations, etc., for *subscriptions only* to ARMY ORDNANCE, and in order to distribute equitably the cost of production of the magazine between membership (including subscriptions) and subscriptions alone, the Board of Directors has directed that the price of *subscriptions only* to ARMY ORDNANCE be set at $4.50 per year, effective on issue of the March-April number. The subscription price to members of the Association only will remain at $3.00 per year as heretofore, this amount being included in the regular membership dues of $5.00.

Members are requested to bring ARMY ORDNANCE to the attention of the Public Libraries in the cities in which they reside, to the Technical Libraries of the firms by which they are employed, and to all other agencies offering a wide field for dissemination of the information printed in the magazine with a view to securing additional *subscriptions*, on which there is no limitation as to eligibility, as distinguished from memberships in the Association, which are open only to American citizens who occupy or have occupied positions which render them of potential usefulness in the production of ordnance in emergency.

Publishing Schedule Resumed

By dint of hard work on the part of all concerned, it has been possible to catch up with our regular publishing schedule. This number, which will be issued in the first week in April, will, therefore, be called the March-April number, and the regular May-June number will be published during the first week in June, 1921. The editorial announcement on page 217 of the January-February (March) number to the effect that the January-February, March-April, and May-June numbers would be combined into two numbers called the January-February-March and April-May-June numbers is accordingly rescinded. The thanks of the Association are due to the clerical force in the Secretary's Office and the publishing force at the Printer's for their strenuous efforts to overcome the unavoidable delay which occurred in printing the January-February number.

Back Numbers Wanted

Requests for back numbers of ARMY ORDNANCE, particularly the July-August, 1920, and January-February, 1921, numbers, are being constantly received at the office of the Secretary. Although 3,880 copies of the latter number, "Ordnance Field Service," were printed, orders for 150 copies in excess of this total have been received and can not be filled unless members who can spare their copies will mail them to the Secretary of the Association at Room 410, Munsey Building, Washington, D. C., and thereby render a real service to the Association by extending the field of its usefulness.

"The Story of American Ordnance"

Through the courtesy of the McGraw-Hill Publishing Company and Mr. K. H. Condit, Editor of the *American Machinist*, the Association has been furnished about 200 copies of the reprint of Maj. John H. Van Deventer's "Story of American Ordnance," which appeared serially in the *American Machinist* in 1919. The Secretary of the Association will be glad to send copies of this interesting series to members upon application, without charge.

Appointments in the Regular Army

There are more than 4,000 vacancies in the commissioned personnel of the army. When promotions under the reorganization law are completed about 1,200 of these vacancies will be in the grade of first lieutenant, the remainder being in the grade of second lieutenant. While it is not proposed to fill all vacancies at present, the necessity for more officers for the army requires that a portion of the vacancies be filled without delay. An examination for appointment will, therefore, be held April 25, 1921. This examination will be competitive for 2,585 vacancies, of which eighty-six are allotted to the Ordnance Department.

The date announced is that of the final examination. Prior to that date applications must be submitted and applicants must undergo a preliminary examination. All applications are to be received and acted upon by corps area commanders who are also charged with conducting the preliminary and final examinations. Details of information concerning examinations for appointment are contained in regulations now being distributed, and application blanks may be obtained at any military post or station. Applications should be submitted by the applicant at the military post or station nearest his place of residence. Writing to the Adjutant General for information or for blanks will only cause delay.

It is contemplated that successful candidates will be announced and appointed, or nominated for appointment, about two months after the examination. Candidates attending schools or colleges will, therefore, have an opportunity to complete the present school year before being appointed.

All successful candidates will be arranged in their order of merit as determined by the final examination and will be appointed in the army in such order. They will also be placed on the promotion list in such order without regard to the branch of the army in which appointed. Those candidates who attain the highest marks on examination will, therefore, have priority in advancement to the vacancies existing as first lieutenant. To be informed as to the full details concerning examinations and appointment, it is necessary that candidates consult the regulations which are being sent to all military posts and stations. However, the prospective candidate's attention is directed to the following:

Eligibility for appointment is fixed by law and requests for exceptions can not, therefore, receive consideration by the War Department. The age at the time of appointment must be between 21 and 30 years. At the time of the final examination each candidate must be in one of the following classes:

(a) A warrant officer or enlisted man of the Regular Army having had not less than two years' service as such.

(b) A member of the Officers' Reserve Corps or the enlisted Reserve Corps.

(c) A member of the National Guard.

(d) A graduate of a technical institution approved by the Secretary of War.

Any civilian of the required age who passes the preliminary examination may readily become eligible to take the final examination and to be appointed by entering either class (b) or (c) above.

Demonstration of Motor Gun Carriages.—On the mornings of February 8 and 9, 1921, the Ordnance Department gave an exhibition and demonstration of Ordnance Motor Equipment of various types in Rock Creek Park, Washington, D. C. The following motor gun carriages were shown in this demonstration: The 75-mm. gun, the 155-mm. gun, and the 3-inch anti-aircraft gun equipped with rubber-tired wheels only. The 75 and 155 mm. motor gun carriages gave a very creditable demonstration of the ability of this type of gun carriage to successfully maneuver rough ground and difficult hills.

These motor gun carriages travelled over the roads from the Aberdeen Proving Ground, Md., to Washington, D. C., for this demonstration, and, in returning, covered the distance of 80 miles in a single day's march. The 75 mm. motor gun carriage was of the conventional caterpillar type and the 155 of the removable track type (Christie), which runs on rubber-tired wheels on good roads. The two types of motor gun carriages, however, experienced no difficulties on this march, which formed a part of the official testing of these experimental vehicles.

Self-propelled Wheeled Mount for 3-inch Anti-aircraft Gun, Model 1917.—The illustration shows the Self-propelled Wheeled Mount (Christie) for the 3-inch Anti-aircraft Gun, Model 1917. During the

war five of these mounts were manufactured by the Front Drive Motor Co., Hoboken, N. J., after the design of Mr. Walter Christie, the president of this company. The first of these mounts, the pilot, was given an extended series of firing and operating tests at the Sandy Hook Proving Ground and on the highways. From data gathered from the tests of the pilot mount four additional mounts were constructed and shipped to the Sandy Hook Proving Ground for further test.

This type of mount represents one of the first attempts to use a self-propelled vehicle for mounting and transporting guns. The gun selected has a pedestal type anti-aircraft mount, as this construction was most suitable for mounting on the frame of the vehicle.

While the vehicle was given the designation of an anti-aircraft mount, its limitations for this service were soon discovered, and because of these limitations, chief among which were its great weight and dependence on good roads, it was not considered acceptable for use in France, or any other place in the field.

During the war the using services in France demanded a type of vehicle which should have greater mobility, higher speed, less weight and other characteristics desirable in vehicles intended for use with anti-aircraft guns. Consequently no additional mounts of this type were manufactured and new developments were undertaken in the caterpillar type, or the combined wheel and caterpillar type, to produce a motor gun carriage more nearly conforming to the requirements.

The Christie type of vehicle was adapted to mounting a heavier caliber cannon more in proportion to its weight and other characteristics. This development has resulted in the present type of Christie wheel caterpillar for the 155-mm. gun, which was illustrated in a previous issue of ARMY ORDNANCE.

The motor gun carriage illustrated, while admittedly not fulfilling all the requirements of an anti-aircraft type, still has a limited field of usefulness. Its particular field of operation would be the defense of cities or other places where good roads are available for transportation. Recently, four of these vehicles have been reconditioned at the Aberdeen Proving Ground for service tests and, more recently, one was exhibited and operated in Washington during the demonstration in Rock Creek Park, having been driven from the Aberdeen Proving Ground under its own power.

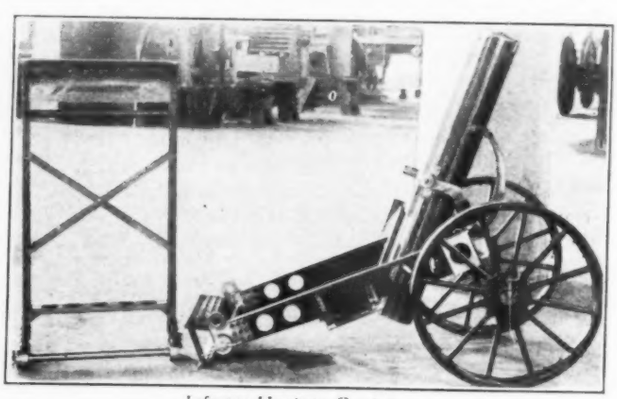
The general weights and characteristics are as follows:

Total weight of vehicle in working order	lb.	36,000
Total weight of gun and mount	lb.	14,000
Maximum overall length of vehicle	in.	224
Maximum overall width of vehicle (on the road)	in.	100
Maximum overall height of vehicle (gun horizontal)	in.	106
Wheel base	in.	144
Size of wheels, 40 inches diameter by 10-inch face, rubber tire center-to-center of treads	in.	90
Maximum road speed	mi. per hr.	12
Normal road speeds	mi. per hr.	7
Gasoline consumption	mi. per gal.	2
Angle of elevation of gun	degrees	0 to 85
Traverse	degrees	360
Range of gun in the air	yards	8050
Weight of projectile	lbs.	15
Turning radius of vehicle	ft.	40
Capacity of fuel tank	gal.	30
Horsepower of motor		60

Type of engine, 4-cylinder, ball-bearing. Type of drive, 4-wheel.

Infantry Howitzer Development.—The manufacture of two infantry howitzers and their carriages has been completed by the Ordnance Department, and these are now en route to the Aberdeen Proving Ground for test. This weapon was designed in the effort to provide matériel which will replace the present 37-mm. Infantry Gun and the 3-inch Stokes Mortar, both of which were used in the World War. Experience indicated that it was necessary to increase the penetrating and destructive power of the former, and the accuracy, power and mobility of the latter; and that it was also desirable, if possible, to replace both in one weapon.

To meet these specifications the new design of howitzer is 2.24 inches in caliber and will fire either a 6-pound or 10-pound projectile. The 6-pound projectile will have a velocity of about 700 foot seconds and is intended for direct fire at low elevations. The 10-pound projectile will be used at the high elevations at a lower velocity, thus fulfilling the present functions of the 3-inch Stokes Mortar. The carriage is so designed that it can be broken up into a number of small loads.



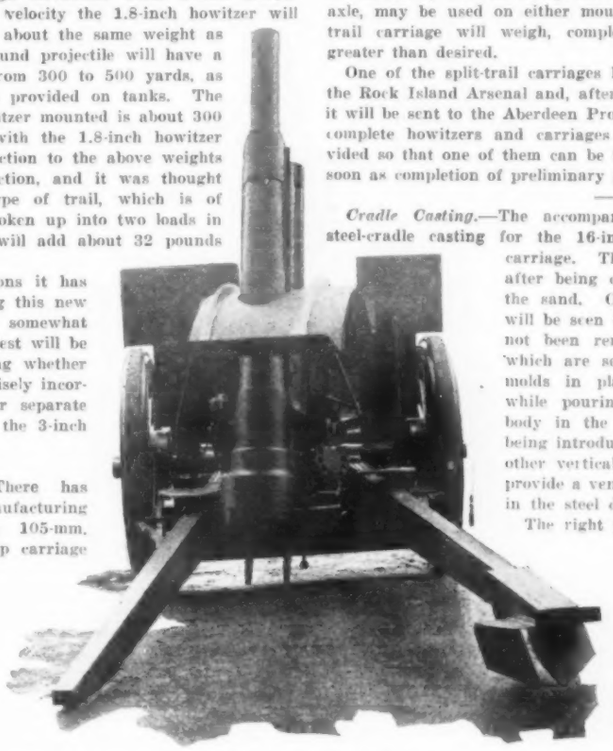
Infantry Howitzer Carriage

varying in weight from 31 pounds for both wheels to 80 pounds for the howitzer proper.

As this howitzer is a somewhat violent compromise between the 37 mm. and the 3-inch Stokes, a 1.8-inch howitzer has been built which is mounted on the same carriage as the 2.24-inch howitzer. Using the 1.8-inch howitzer, either a 3-pound or 6-pound projectile may be used, the 3-pound projectile being for use at low elevations in direct fire and the 6-pound projectile for high elevations when trench mortar effect is desired. Due to its high velocity the 1.8-inch howitzer will weigh about 90 pounds, this being about the same weight as the present 37-mm. gun. The 3-pound projectile will have a velocity sufficient to penetrate at from 300 to 500 yards, as heavy armor as can reasonably be provided on tanks. The total weight with the 2.24-inch howitzer mounted is about 300 pounds, including the sight, and with the 1.8-inch howitzer mounted, about 310 pounds. Reduction to the above weights has necessitated very light construction, and it was thought desirable to build an alternate type of trail, which is of heavier construction and will be broken up into two loads in transporting. This trail, if used, will add about 32 pounds to the total weight.

In view of the unusual conditions it has been necessary to meet in providing this new weapon, its ultimate success is somewhat doubtful. On the other hand, the test will be of considerable value in determining whether the characteristics desired can be wisely incorporated in one weapon or whether separate developments of the 337 mm. and the 3-inch Stokes Mortar will be preferred.

105-mm. Howitzer Matériel.—There has been delivered to the Holt Manufacturing Company at Stockton, Calif., a 105-mm. howitzer and a recuperator and top carriage for assembly to a caterpillar mount being made under contract at Stockton. The howitzer was manufactured at the Watervliet Arsenal, and given a preliminary test on the recuperator at the Rock Island Arsenal before shipping it to the Holt Company for further firing on the caterpillar mount itself.



The New 105-mm. Howitzer

This howitzer is the one being made under the development program as a companion piece to the new 75-mm. field gun, and the howitzer is interchangeable on the mount with the gun. The weight of the howitzer is about 1,270 pounds, which is 330 pounds greater than that of the gun, but this difference in weight is not sufficient to affect interchangeability.

A recuperator of the St. Chamond type is used, giving a recoil of 45 inches at zero elevation, decreasing to 330 inches at the maximum elevation of 80 degrees. It is expected that a maximum range of 12,000 yards can be obtained at an elevation of approximately 45 degrees, using a 33-pound projectile.

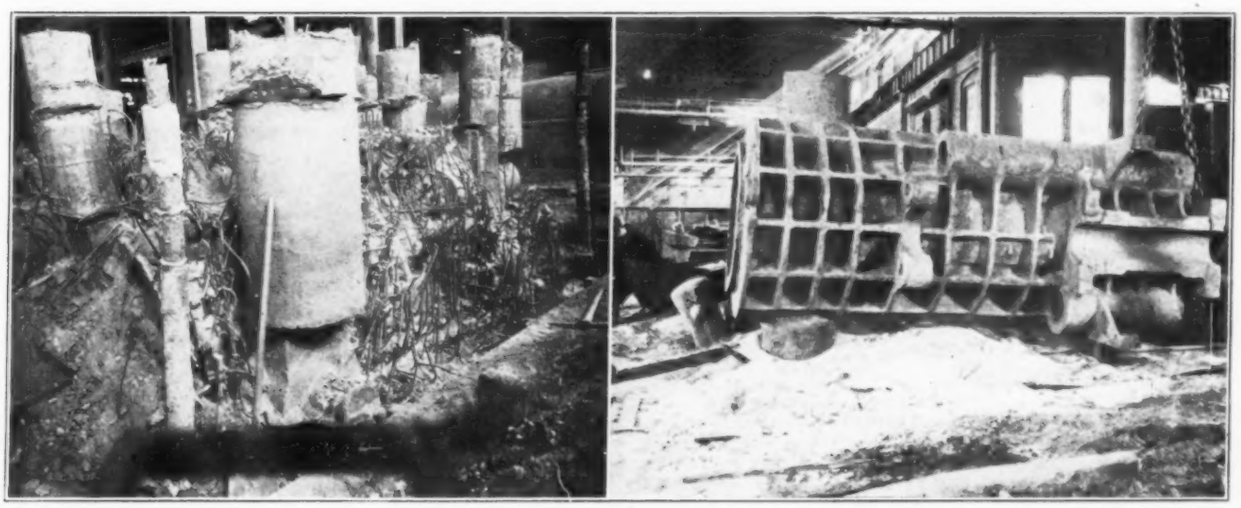
The program of development contemplates that each caliber of field gun will be mounted for experimental purposes on both a wheeled and a caterpillar mount. In accordance with this policy, wheeled carriages have also been built for mounting a similar 105-mm. howitzer. This carriage is of the split-trail type, and permits elevation from zero to 80 degrees, and 30 degrees horizontal arc of fire. For the sake of interchangeability the caterpillar and wheeled mounts are so designed that the howitzer, with its recuperator and parts of the carriage above the axle, may be used on either mount. In the firing position the split-trail carriage will weigh, complete, about 3,700 pounds, which is greater than desired.

One of the split-trail carriages has been given a preliminary test at the Rock Island Arsenal and, after some corrections, if found desirable, it will be sent to the Aberdeen Proving Ground for extended test. Two complete howitzers and carriages of the split-trail type will be provided so that one of them can be turned over to the service for test as soon as completion of preliminary proof at the Proving Ground.

Cradle Casting.—The accompanying illustrations show a fifty-ton steel-cradle casting for the 16-inch, 50-caliber, seacoast-defense gun carriage. The left photograph shows the cradle after being cast, but before being removed from the sand. On the left-hand side of the picture will be seen the end of the main core, which has not been removed. The numerous small wires which are seen are used to keep the cores and molds in place to prevent moving or shifting while pouring the steel. The large cylindrical body in the foreground is the sprew, the steel being introduced into the mold at this point. The other vertical bodies are risers, and are used to provide a vent for the air and for other impurities in the steel during the pouring.

The right photograph shows the casting undergoing the cleaning operation to remove the sand and scale from the exterior. The large cored hole running longitudinally through the center of the casting receives the gun. The trunnions, which support the gun during firing, are located near the left-hand end of the casting. The two cylinders, cast integral, seen at the upper and lower right-hand end, are the recoil mechanism. Two similar cylinders are also located on the opposite side of the casting. The cylindrical recesses between the recoil cylinders receive the hydro-pneumatic mechanisms which return the gun to the firing position. The over-all length of this large casting is approximately 15½ feet, and the height of the casting, measured from the end of one trunnion to the other, is 9½ feet.

Commercial foundries capable of producing steel castings of this size are few and far between, and commercial machine shops equipped to finish single pieces of this size to the high degree of accuracy required are even scarcer. Consideration of these facts explains the great length of time required to produce heavy ordnance.



In the sand — Steel Casting for 16-inch Gun Carriage — Partially cleaned

German Long-Range Gun.—The following table shows the daily fall of shells from which the deduction as to the number of guns used in the Paris bombardment was developed, in the article in the last issue of this publication, by Maj. K. F. Adamson, Ordnance Department, on the German long-range gun:

DAILY FALL OF SHELL IN PARIS BOMBARDMENT

1918	In Paris	Out of Paris	Total	Total of Group	Percent of Hits	Percent of Hits of Group
March 23	18	3	21		72	68
24	13	9	22			
25	4	2	6		50	
29	1	3	4	53		
March 30	18	3	21		87	75
31	3	0	3			
April 1	3	1	4			
2	3	1	4			
3	1	0	1			
6	2	4	6		29	
7	0	1	1	40		
April 11	5	1	6		77	63
12	5	2	7			
13	6	2	8			
14	3	1	4			
15	3	2	5			
16	2	1	3			
19	1	2	3			
21	2	0	2			
24	0	1	1			
25	6	4	10			
26	1	0	1			
30	0	3	3	54	20	
May 1	0	1	1			
May 27	7	7	14		55	41
28	6	4	10			
29	5	5	10			
30	4	5	9			
31	1	3	4			
June 1	0	4	4		7	
3	0	6	6	57		
June 4	4	0	4		87	71
7	3	1	4			
8	1	2	3			
9	1	3	4			
10	2	2	4			
11	0	1	1			
July 15	9	1	10			
16	4	0	4	34		
August 5	13	4	17		70	55
6	12	7	19			
7	8	4	12			
8	1	4	5		18	
9	2	10	12	65		
Total	183	120	303		280	60

WATERTOWN ARSENAL NOTES.

Auto-Frettage.—Those readers of ARMY ORDNANCE who have been reading the articles on Auto-Frettage will be interested in the accompanying tables which give extracts from the official data that was obtained while auto fretting the 155 mm. howitzer, Model 1921.

The tremendous pressures required for this work were furnished by the million-pound Emery Machine at the Watertown Arsenal. The actual process of auto-fretting was accomplished by forcing a plunger into the gun tube which was filled with water. This water was retained by means of cup packings that were properly backed up, on one end, by a solid steel plug and, on the other, by a hollow steel one through which the plunger travelled. As this advanced it displaced the water which in turn caused the dilation of the tube. The pressure that was required on the plunger to produce the desired dilatation was found to be 815,000 pounds, which is the equivalent of 64,900 pounds per square inch.

At seven different sections along the forgings external measurements were taken in three places around the circumference in order to detect any elliptic distortion. The apparent difference in diameters for any one set of readings is not due to such distortion, however, but is due to the fact that the bands which were turned on the tube for measuring purposes were given their final finish by hand filing. This introduced the personal element and destroyed the exact circular contour. If each measurement is compared with its succeeding one in the same location, no difficulty will be found in following the trend of dilatation.

In accordance with instructions from the Ordnance Office the tube was subjected a second time to internal pressure but only to a magnitude of 60,000 pounds per square inch on the plunger. This test differed from the first one in that the pressure was not advanced by successive steps directly to the maximum but was increased by degrees to a certain predetermined pressure and then returned by the same number of successive steps to the starting point. This cycle was repeated four times before reaching the maximum. In spite of the fact that the pressure reached in this second test was within 5,000 pounds per square inch of the first one, no additional permanent set was obtained for, when all pressure was removed, the tube returned to the size it was before starting the test.

The measurements given are for one section near the middle of the forging. Check readings were taken but are not given in the tables.

TABLE I.

Measurements of External Diameters in inches of Auto-fretted Forging for Different Hydraulic Bore Pressures.

Lbs. per sq. in.	External diam. of forging	Lbs. per sq. in.	External diam. of forging
0	11.795	50,000	11.8125
0	11.794	52,000	11.8145
0	11.795	54,000	11.817
5,000	11.797	56,000	11.8195
5,000	11.7965	58,000	11.8225
5,000	11.7965	58,000	11.822
10,000	11.7985	58,000	11.8215
15,000	11.7985	5,000	11.811
20,000	11.7995	5,000	11.8095
22,000	11.8005	5,000	11.8095
24,000	11.801	60,000	11.833
26,000	11.80175	62,000	11.840
28,000	11.802	62,000	11.839
30,000	11.8025	62,000	11.838
32,000	11.803	0	11.8285
34,000	11.804	0	11.8275
36,000	11.805	0	11.827
38,000	11.805	64,900*	11.861
40,000	11.80625	64,900*	11.860
42,000	11.807	64,900*	11.859
44,000	11.8085	0	11.8435
46,000	11.80925	0	11.8425
48,000	11.811	0	11.841

*Check readings omitted because of rapid flow of metal.

Three measurements were taken for each pressure at points 60 degrees apart on each section, but only a few of the complete series are given above because of limited space.

TABLE II

Diameter of bore at several points along bore by star gauge in inches before and after application of internal hydraulic pressure.

Distance from large end of tube	Original bore	Bore after int. pressure 58,000 lbs. per square inch	Bore after int. pressure, 64,900 lbs. per square inch	Bore after int. pressure, 60,000 lbs. per square inch, second application
8.5	6.4005	6.4175	6.436	6.4385
43	5.79975	5.818	5.857	5.856
87	5.79975	5.827	5.893	5.893
129	5.79975	5.8265	5.890	5.890
151	5.79875	5.824		

TABLE III

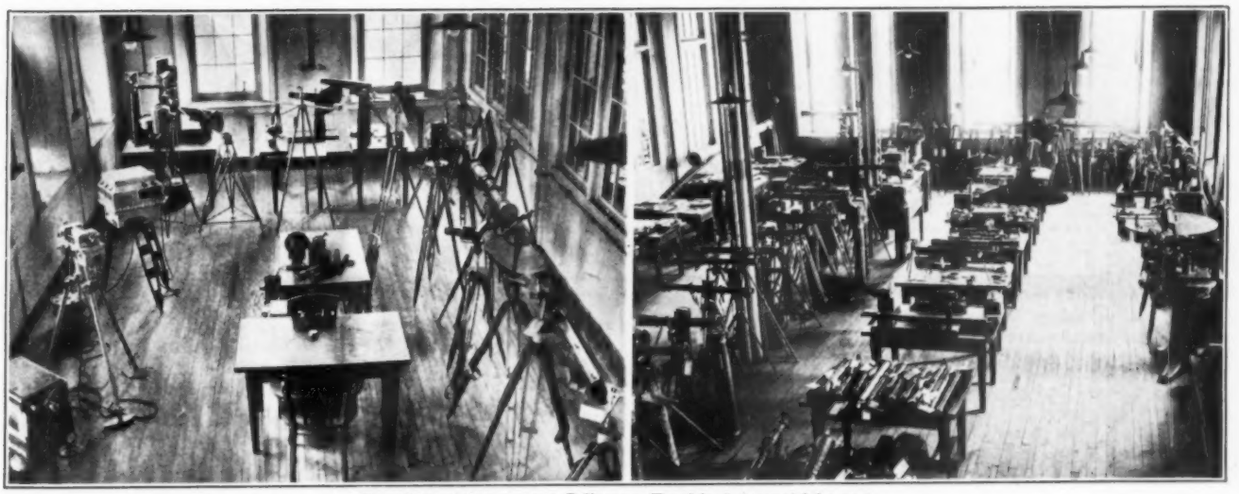
Record of external measurements on auto-fretted forging applied one (1) month after auto-fretting, per Table One (I). Measurement taken at same point as in Tab'e One (I).

Lbs. per sq. inch	External Diameter inches	Lbs. per sq. inch	External Diameter inches
5,000	11.845	40,000	11.8545
10,000	11.8455	30,000	11.8515
20,000	11.848	20,000	11.8485
30,000	11.850	10,000	11.846
40,000	11.853	5,000	11.8445
50,000	11.856	0	11.8435
60,000	11.860	0	11.8435
50,000	11.857	*	

* Four Days Later.

Experimental Packing.—The packing used in the recuperator of the 155-mm. Schneider Howitzer consists of two rubber rings of certain specified qualities. One of these rings, which is designated as "dermatine," is in contact with the moving parts, and this dermatine ring is backed up by the larger rubber ring, which, being held under compression by Belleville springs, holds the dermatine ring in intimate contact with the sliding part.

Experience with this packing has shown that it deteriorates rapidly and is very difficult to keep in good condition. When left standing for an appreciable length of time under pressure, the dermatine ring



Fire Control Instrument Collection, Frankford Arsenal Museum

very naturally seizes to the metal, and when these parts then move in recoil, the packing is badly injured. The elasticity of the parts back of the dermatine apparently compensate to a considerable degree for this abrasion of the dermatine, and the packing holds pressure fairly well, even though in poor shape.

As continual replacement becomes necessary, however, the Ordnance Department has been conducting experiments with a view to replacing the dermatine ring with a ring of chrome leather. A number of these leather rings have been made and substituted, and shop and firing tests conducted at Rock Island Arsenal. In making the first test, the cylinders were filled with a prescribed mixture of glycerine and water, and it was found that apparently the lubrication received from this mixture was not enough to prevent abrasion and tearing of the leather, although the metal parts were highly polished. The cylinders were then filled with hydroline, which is a very light oil, and somewhat similar results were obtained. The cylinders were next filled with a heavy recoil oil, being carefully lubricated before assembly, and in this case the leather packing was found to function quite well.

This test, however, is by no means conclusive, for it must yet be determined whether it is possible to use an oil in the mechanism in place of the glycerine and water. It must be understood that the complete designs and specifications for this matériel having been received from the French during the war, it is impracticable to make any changes until it can be conclusively shown that such changes lead to improvement. The practice prescribed by the French was undoubtedly arrived at after extended experiment, and before either confirming or rejecting this practice, extended proving ground and field tests will be necessary.

THE FRANKFORD ARSENAL MUSEUM

In accordance with the general policy of the Ordnance Department, there has recently been established at Frankford Arsenal an Engineering Collection of Fire Control Instruments, as well as such items of small arms ammunition and artillery ammunition as was available. The collection is housed in the old stock department building and occupies both floors of the main part of the structure, leaving room for expansion, if necessary, to the wings.

The collection, at present, is made up largely of fire control instruments, since the variety of matériel of this class available from the general reserve at the arsenal is far in excess of that of the other items manufactured at the arsenal. It is hoped, eventually, to obtain many more exhibits of small arms and artillery ammunition and fuses so that the collection will be complete.

There are at present in the Museum some 1,200 separate items of fire control matériel, About forty per cent of these items were collected from various storehouses at the arsenal, including samples of the earliest experimental types of range finders, gun sights, quadrants, etc., developed in this country or purchased abroad for test in our service. This part of the collection is interesting chiefly from a historical standpoint, since most of the items were either found unsuitable for the service, or have been made obsolete by later development.

Of the remaining sixty per cent, about one-tenth is composed of instruments captured during the war, and the balance, of items used by our troops in Europe. It is evident from a casual inspection of the captured items that the enemy took unusual care to insure that as few as possible of his fire control instruments fell into the hands of the allies, and that such as were captured should contain little of value in the way of new design. The bulk of these items consists of gun sights manufactured previous to the war, with few features of other than historical interest. There are, however, a few range-finders of various lengths and some other instruments in which novel ideas have been incorporated. These ideas will be tested in our service to determine if they have any particular value. As is usual with apparatus manufactured in Germany, the design of these items is well thought out and the class of workmanship excellent. As is to be expected, this is particularly the case with reference to optical systems, in the construction of which the firms of Zeiss and Goerz have long been preeminent. Study of these designs is being made with a view to possible application in our service.

The Museum contains a sample of nearly every item of fire control equipment in current use in the service; also samples of all those which were purchased abroad for the use of the expeditionary forces and which are now in reserve. Since few instruments of domestic manufacture ever reached the front, practically all of those used by the A. E. F. were procured from the French or British. The Museum is, therefore, quite complete in regard to samples of French and British matériel.

A special room in the Museum has been set aside for anti-aircraft instruments and the collection is complete in regard to those used by the allies during the war. Since the French were the pioneers in this branch of warfare, and the system in use by all of the allies was that developed by the French, this apparatus is entirely of French manufacture, with the exception of a few experimental items obtained from the British after the armistice.

The Germans seemed to be particularly careful that little of their anti-aircraft fire control fell into the allied hands, hence the Museum possesses only an odd instrument or so, from which it is possible to get merely a fragmentary idea of the system they used. It might be stated, however, that from other sources of information, it has been quite well determined what were the details of their apparatus.

The influence of trench warfare on the design of observation instruments is very evident from a casual inspection of the collection. The necessity for protecting an observer working in advanced trenches made imperative the application of the periscopic feature to such instruments as the alidade, the azimuth instrument, and the observation telescope, and the development of a cheap type of hand periscope which could be issued to front line troops. Many examples of this class of trench matériel will be found in the collection. Captured instruments of this type are numerous, as is to be expected, due to the fact that they were used in the advanced trenches which often had to be abandoned, leaving the equipment to its fate.

The cataloging of the collection is not yet complete, due to the difficulty in obtaining the correct nomenclature of all the items. As far as practicable, however, tags have been attached to each instrument giving such information as will enable a non-technical visitor to determine the general use for which the instrument was intended.

The collection will be added to from time to time, from new matériel under manufacture or purchased. The position of the arsenal as the engineering, manufacturing and general storage center for fire control instruments, makes it the logical place at which to maintain the engineering collection.

The accompanying illustrations show the general arrangement of the instrument section of the Museum. The anti-aircraft instruments are housed in the part partitioned off from the rest of the exhibit.

The 16-inch disappearing carriage, model of 1917, mounting the 16-inch 50-caliber gun, has been received at Aberdeen Proving Ground from Watertown Arsenal. The erection of the carriage is about 50 per cent complete. The 16-inch howitzer carriage, model 1920, is being assembled at Watertown Arsenal and it is expected that the pilot carriage will be completed during the month of June.

ROCK ISLAND ARSENAL NOTES

ORDNANCE ENGINEERING SCHOOLS

Too much cannot be written about, or commented upon, the book written by General Crozier, "Ordnance and the World War," and, no doubt, it will take years to make the Public believe that General Crozier has been, and is being, unjustly condemned and criticised.

We all know that our Government was not prepared for extensive warfare in 1916, and we also know that the men in control of the military affairs at that time will not assume the responsibility for not being prepared. General Hagood states, on page 67 of the September-October ARMY ORDNANCE, that "In all its history the United States has never yet made a correct estimate of the military situation until it was actually engaged in war, or usually until the war was half over." This applies to the manufacture of ordnance material as well.

The question is, "What are we going to do about it?"

No doubt, in organizing the A. O. A. a great deal of valuable work is being done, and will be done in years to come, to help convince Congress and make the public believe that preparedness is necessary to uphold the peace of the world.

The officers and the management of the A. O. A. are men of such high standing in the manufacturing and business world, and their experience and assistance in the last war was so vast, that they may have more influence with Congress to provide funds for preparedness than the army officers have had in the past. All of the wonderful writings and the data collected and submitted by ARMY ORDNANCE in the future will, no doubt, bring about the best of results, but there is one item overlooked, and that is "Actual training of engineers for ordnance manufacture in case of any future wars."

It is with this in mind that a suggestion is submitted, and it is that all government arsenals and engineering schools should be established where men could be trained in the management and production methods of all ordnance material. This should not be for only a few months' course, but for years of steady study in engineering, designing, production, and shop management. The government should make these positions as attractive as possible and pay salaries equal to, or better than, those paid in private manufacturing plants. All arsenals should be operated at peace-time production and all material should be manufactured there, so that the engineers be given the fullest opportunity to develop the best production methods possible.

The writer cannot agree with what General Williams says on page 54 of the September-October issue of ARMY ORDNANCE—"Orders for ordnance material should, as far as practicable, be placed with private concerns, so that the engineering staffs and workmen of these concerns may be skilled in the design and production of war munitions." We know that the average manufacturer in peace time does not handle the manufacture of ordnance material from a patriotic standpoint, but from a financial standpoint, and the general attitude of manufacturers is expressed in the editorial on page 84—"Never again."

The average engineer and workman at these private plants do not familiarize themselves with ordnance material in order to become experts. This has been proved during the World War, as very little information was obtainable on modern production methods of ordnance material, due to private manufacturers being rushed with work for the Allies, and the arsenals not having a large trained force which could be turned over to private manufacturers for our ordnance work. This result was, as we all know, considerable delay in methods of production, inspection, and general management of ordnance material.

If there had been a trained corps of ordnance engineers educated at Government arsenals, even though these engineers had returned to private practice years ago, they would have had sufficient training to be in a position to train others more quickly in the manufacture of ordnance material than the new men could educate themselves. The officers in the Ordnance Department are not of sufficient number to take care of the manufacture of ordnance material in war times, in fact, in most cases those mostly experienced with the manufacture of ordnance were sent to the front for observation purposes, and replaced by reserve officers not familiar with or qualified for manufacturing ordnance material.

Our officers are educated at West Point in everything necessary to win battles and to win wars; this they have proved again in this last war, and the writer believes as General Charbonniers when he states, as on page 52 of the September-October, 1920, issue of ARMY ORDNANCE, that "it is impossible for one man to be trained in, and to embrace, everything necessary to make war. This is to say, we must allow the two sciences, military and technical, to specialize."

Well, why not let our engineers develop and manufacture our war munitions, and our officers direct how to use them? The experience gained in the last war should teach us that we must develop more and more modern and mechanical ordnance material than ever before, and this means engineers.

No criticism is intended against officers of the Ordnance Department and those in charge of arsenals, as these men are of the highest types of executives, but, as stated before, they do not know themselves where they may be located in case of emergencies, and when replaced by reserve officers, no matter their standing in the manufacturing world, too much time is wasted to bring about satisfactory production results.

It should be the aim of the Army Ordnance Association to convince Congress that money spent in peace times for educating engineers at government arsenals would be money well spent, as it would be better to spend millions in peace times than billions in war times, and the work as now outlined by our Army Ordnance Association would be the greatest success if trained engineers were on hand in case of emergencies to follow the aim of this organization.

WM. BAUMBECK,
Member A. O. A.

ORGANIZATION OF TWENTY-FIVE-YEAR ORDNANCE SERVICE CLUB, ROCK ISLAND ARSENAL

Our Motto—Patriotism and Co-operation

More than 1,000 persons attended the banquet and program given by the Twenty-five-Year Ordnance Service Club at Rock Island Arsenal on the evening of February 21, 1921. The unusually large attendance was a source of genuine surprise to officers and members of the club, and covers were laid for 911 people for dinner in the cafeteria, showing the respect and esteem in which this organization is held by 2,600 other employees of this arsenal.

The banqueters were addressed by the Commanding Officer in a congratulatory manner for the splendid service given by the seventy odd club members and also upon the success of the Works Council now thoroughly established at this arsenal. Following the address, the president of the club remarked on the splendid showing of the organization and told naratives from Colonel Flagler's time to the present. A number of amusing incidents were recounted by him during his talk.

Following the banquet the guests adjourned to the Y. M. C. A. Welfare Hut on the arsenal grounds, where an elaborate program was given which proved highly entertaining. More than 200 persons who had not been seated at the banquet tables were present during the program.

The dialect selections were unusually good, and brought much applause from the audience. The classic dancing showed professional ability, and was encored repeatedly.

Probably one of the features of the evening was the minstrel. Very few professional assemblies are found endowed with more entertaining power than the minstrels that were produced last evening. The jokes were new, the dancing and singing good, and the entire production was without a dull moment.

All the talent presented in the program, however, was furnished by the employees of Rock Island Arsenal. The result is a splendid spirit of co-operation and good-fellowship throughout the entire personnel of the arsenal.

During the banquet a telegram was received from the Watervliet Arsenal Club, of New York, congratulating the local association on its progress.

R. C. MUNSON.

The 75-mm. Pack Howitzer and Carriage, Model 1920.—The pilot 75-mm. pack howitzer carriages, model of 1920 (Nos. 1 and 2), have been recently completed at Rock Island Arsenal and shipped with howitzers Nos. 1 and 2 to Aberdeen Proving Ground for extended test. As the name indicates, the matériel is designed to be separated into units suitable for pack transportation.

The howitzer rests on a sleigh, which slides in ways in the cradle formed by the recoil and recuperator cylinders. The trunnions of the cradle are set well back in order to provide for maximum recoil at high angles of elevation, and the resulting muzzle preponderance is, in a measure, overcome by the use of spiral equilibrator spring operating to produce a torque in the elevating pinion shaft. The model 1920 howitzer has a sliding breech block, and the model 1920 M1 a screw block. Both are fixed by lanyard only, there being no firing mechanism provided on the carriage.

The principal parts of the carriage are the cradle and sleigh, upper trail, lower trail, elevating mechanism, axle and wheels.

The Recuperator and Sleigh.—The recoil mechanism is St. Chamond hydro-pneumatic type, with variable recoil, and has three longitudinal bores; the oil reservoir and pump are on the right in rear of the air reservoir, the floating piston and variable recoil valve in the left, and the recoil piston rod in the middle. The piston rod is indirectly connected through the sleigh to the howitzer.

The Wheels and Axle.—The wheels are steel tired, wood spoke, artillery type, 29 inches diameter, so arranged at the hub that the hub box revolves on the liner, which is prevented from turning by engagement with the axle. The wheel fastening consists of a spring latch and plunger in the hub cap engaging a button on the end of the axle arm. Pressing on the plunger releases the latch, and the wheel with the hub liner may be taken off.

The Trail.—The lower section of the trail is made to fold forward on the upper section to reduce the length of the pack load. Each section is built up of flange-steel side plates, or flasks, connected at the lower end of upper trail by a flange-steel transom, at the hinge joint by the hinge pins, and by the spade. The lower section also has a stiffening transom midway its length.

The upper trail is open to allow the howitzer to pass between the flasks when firing at elevations. Traverse is accomplished by sliding the forward end of the trail along the axle. Cast bronze axle bearings on the forward ends of the upper trail flasks are formed to embrace the axle with a section cut away, so that when the axle is turned in a certain position flats on the axle coincide with the openings in the bearings and the axle and trail may be separated. This turning of the axle is accomplished by the axle lever mounted in the right axle bearing. The traversing hand wheel on the axle has a seat in the left axle bearing on the trail. When the axle is assembled, revolution of the hand wheel forces the trail along the axle, pulling the top of the hand wheel to the rear traverses the carriage to the right; 2½ degrees traverse to right or left of the central position is secured.

Two types of trails have been manufactured for trial, one having the openings in the axle bearings for the axle forward, and one with these openings underneath. Carriage No. 1 has the forward openings. Another point of difference between carriages No. 1 and No. 2 is that No. 2 trail is provided with folding seats. The trunnion bearings of the trail (also bronze castings) are not supplied with caps. Instead, hooks (trunnion locks) are mounted on the trunnions of the cradle which engage the projecting under surfaces of the trunnion bearings.

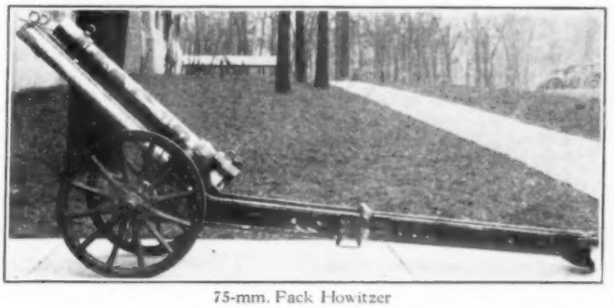
Elevating Mechanism.—Elevation is accomplished through a pinion and a segment of a spur gear, called the "elevating arc." The ends of the elevating arc rest in seats in the under surface of the cradle, the pitch line of the arc being concentric with the trunnions. The elevating hand wheels revolve the pinion meshing in this arc, through which the movement is transmitted to the cradle. When the cradle is dismounted for pack the elevating arc remains in the trail-elevating housing, being retained by embracing lugs of the housing.

The train of elevating gears includes a Hindley worm, with shaft resting in ball bearings, rather an unusual combination. Revolving the right elevating hand wheel in an anti-clockwise direction operates to elevate the piece.

The equilibrator springs rest in slots in the ends of the elevating pinion shaft, and the position of these slots is important to produce tension in the springs greatest at depression. Therefore, when the elevating arc is removed for any reason, it must be replaced with the proper assembling marks on arc and pinion coinciding.

Pack Outfit.—For pack purposes, the howitzer recoil mechanism and carriage are divided into four pack-mule loads. To disengage the howitzer from the sleigh, the locking lever under the breech is pulled to the rear. The breech is then raised until the rear lug is free from its seat and the howitzer moved slightly forward to disengage from the ball at the forward end. Rings for the lifting bars are provided at the muzzle and breech of the howitzer and on the forward ends of cradle and trail. The bars may be inserted through holes in the rear end of the upper trail and behind projecting hooks at the rear of cradle. The sleigh remains with the cradle in pack, as do also the cradle trunnion locks. The axle and wheels, sight chest and sponge form another load, and the folded trail the fourth. The pack outfit necessary consists at present of the standard pack harness, blinder, blanket, corona, aparejo, sobrejalma and crupper and the following special pack equipment:

Each load requires a pack frame consisting of two arches (super frames) hinged to two standard pack frame sides. The howitzer is retained on this pack frame by quick-action spring retainers ("Pack Locks") on each super frame. Cinches are used for the cradle and trail loads. Axle adapters are required on the super frames to hold the axle at the required height, in which the axle is retained by a spring device similar to that used for the howitzer. The wheels are mounted on hangers which simulate the axle arms and are held on



75-mm. Pack Howitzer

these hangers by the spring fastenings in the hub caps. Four lifting bars, each of which may also be used as a hand-spike or a sponge staff, are part of the special pack equipment.

Weights of Pack Loads—

	Pounds
No. 1—Howitzer	207
Harness and equipment	102
Total	309
No. 2—Cradle and sleigh	239
Harness and equipment	103.3
Total	342.3
No. 3—Wheels (29 in.)	99
Axle, complete	46.5
Lift bars and sponge	27.5
Harness, etc.	120.8
Total	293.8
No. 4—Trail	222.5
Harness, etc.	104.2
Total	326.7

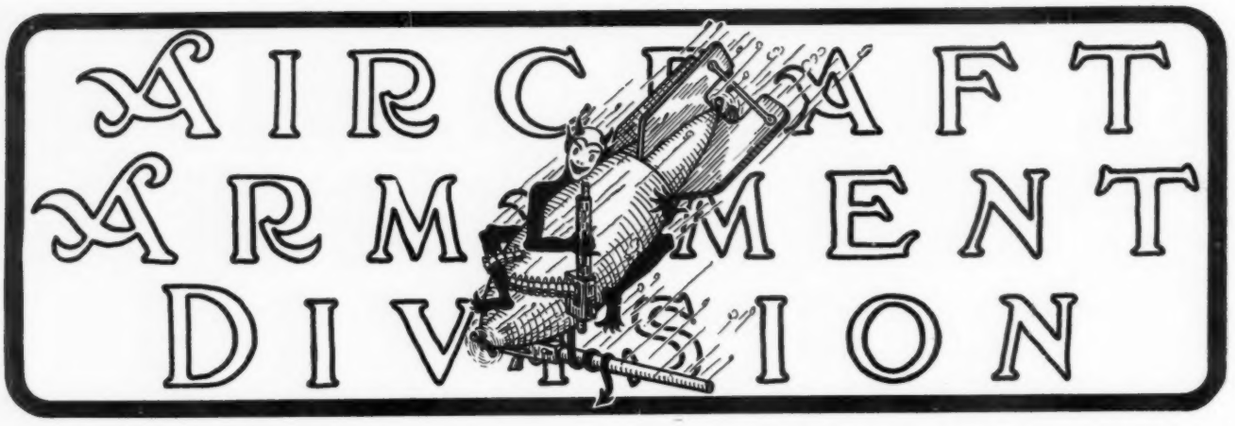
WATERVLIET ARSENAL NOTES.

16-Inch Guns.—16-inch Army Gun, No. 3, has been rifled and No. 4 should be rifled in the early part of April. The so-called White-Type Rifling Head used in rifling these guns has proven itself entirely satisfactory. 16-inch Army Gun, No. 2, was shipped to Watertown Arsenal for assembly on the carriage. The weight of this gun was 317,480 pounds without the recoil band—weight of the recoil band was 57,630 pounds.

Infantry Howitzer.—Two 1.8-inch and two 2.24-inch howitzers were completed during the month. These are type guns manufactured in accordance with recommendations of the caliber board.

Experimental Rifling.—The last one of six 5-inch, Model 1897, Guns converted to 3.3-inch Guns was completed and shipped to Aberdeen Proving Ground for test. The type of rifling used in this gun is of a continuous taper throughout its length—the length of rifling being about 170 inches with a depth of .03 at the origin with zero depth about 18 inches from the muzzle.

The 16-inch barbette carriage, model 1919, is now being erected at Watertown Arsenal, and it is expected that the carriage will be ready for shop test early in April. The carriage will be complete except for the electrical equipmnt and electric rammer. All parts of the design of the 16-inch barbette carriage, model 1919, have been completed with the exception of the ammunition packing trays, ammunition transport cars and 360-degree electrical contact and wiring.



Bombs

Recent tests on delay elements of bombs would indicate that a solution has been reached of a difficulty which has been causing some trouble. It was found that the delays which were being produced would function satisfactorily in bombs dropped on land but gave unsatisfactory results in bombs dropped on water. It was quite difficult to locate the trouble as the bombs dropped on water could not be recovered. In a recent test held by this Department at Aberdeen Proving Ground, which was witnessed by General Mitchell, bombs fused with new delays functioned very well over water, and it is felt that the trouble has been overcome. Tests will be extended however to make sure of this point. It is quite essential that the delays act on water as on land, as it is proposed to use our Demolition Bombs in the bombing maneuvers which will be held sometime this summer in which a battleship will be attacked.

The new nose and tail fuses being developed by Frankford Arsenal are progressing satisfactorily. These fuses will be a decided improvement over the present ones. The booster to be used in the ellipsoidal one developed for artillery ammunition. There was some question as to whether or not this booster would properly detonate the large amount of explosive carried by our bombs, and tests have been recently held to test this out. Bombs as large as the 1100-pound Demolition Bomb, which carry approximately 600 pounds of explosive, have been successfully detonated by this booster.

Orders were recently placed with Rock Island Arsenal for new 100-pound, 300-pound, 600-pound and 1,100-pound Demolition Bombs. The construction of the 1,100-pound bombs is being expedited in order that they may be used, if needed, in the proposed bombing maneuvers against naval vessels.

The design of a 2,000-pound Demolition Bomb has been completed, and several of these bombs are being manufactured. These bombs will be tested and a few of them may be used in the proposed bombing maneuvers.

The design of a 4,000-pound Demolition Bomb is just being completed in the drafting room. It is proposed to construct a few of these and test them. It is doubtful whether any of them can be completed in time for them to be used in the proposed bombing maneuver, but if any can be completed, it is probable some of them might be used in this test.

The past month has been an extremely active one, and one quite similar to war-time days when everybody worked overtime. This strenuous time is still continuing, as it is not proposed to have the Ordnance Department behind in furnishing the material required for the bombing maneuvers against naval vessels planned by the air Service.

The 8-ounce incendiary bombs have been completed and shipped to Edgewood Arsenal where they are being loaded. In this connection, it is interesting to note that during a recent static test on Demolition Bombs, that a very serious fire was started at Aberdeen Proving Ground which might have caused considerable damage had not a thunderstorm come up and the rain put out the fire. There are differences of opinion as to the necessity for Incendiary Bombs. There is this much that can be said for explosive bombs, that they always do some damage, and if conditions are satisfactory, they are good incendiary agents themselves.

A 1,100-pound armor piercing bomb is under development. Several of these have been manufactured and are awaiting test at Aberdeen Proving Ground. These bombs have been made up by converting the 12-inch deck piercing shell.

As it is proposed to use some of the British 1,600-pound bombs which were shipped from abroad to this country, in the bombing maneuvers, twenty dummy bombs were made up by Frankford Arsenal to be used in practice. Great credit is due Frankford Arsenal for getting twenty of these bombs out in one month. The bombs were made of a thin steel casing filled with concrete.

The first series of model bombs for wind tunnel testing have been completed and turned over to the Bureau of Standards for test. These models were designed by Captain Short. The bombs are made up of three sections, a nose ogive, a body section and a tail ogive. These are bolted together and it is possible to change the nose and tail ogives and the body section. By the wind tunnel test, it is expected that the effects of varying the nose and tail ogives and the center sections will be found, and can be used in the future design of bombs. On these models, fins are detachable and various forms of fins are to be assembled to different models to try out the effect of each. It is expected in these tests to find out the best form of fin for use with bombs.

So far this spring, it has not been possible to get any ballistic films at Aberdeen and the question is now being seriously considered of transferring this activity to some locality where this ballistic work can be taken care of to better advantage. Winter interferes with this work at Aberdeen, no reflections being obtained over ice and the crosses in the water are always taken out with the ice and have to be replaced. It is quite probable that the activity will have to be located some place further south.

Bomb Sights

The tests of the Mark IA Sight and the Navy Mark IIIA Sight have been practically completed. It will be remembered that the Mark IA Sight is a copy of the English Wimperis Drift Sight, and the Navy Mark IIIA Sight is a copy of the Wimperis Course Setting Sight. The tests have been sufficiently conclusive to demonstrate that the Navy Mark IIIA Sight is better for bombing than the Mark IA. This Department is procuring a certain number of these sights from the Navy to be used by our service as required. These sights will be used in the bombing maneuvers. Captain Loring has designed a new height scale to be used with the Navy Mark III Sight, which is a low altitude sight, so that the sight can be used up to about 8,000 ft. About half of the sights procured from the Navy will be equipped with this new height bar.

Lectures have been given by members of this Division at Langley Field before the officers at that station on bombs and bomb sights. These representatives conferred with officers of the Air Service regarding the equipment to be used by the Air Service in their bombing maneuvers.

Bomb Racks

In view of the fact that the Air Service proposes to use the British 1,600-pound bomb in their bombing maneuvers, an order has been placed with Rock Island Arsenal for the construction of a few bomb racks for these bombs. These bomb racks will probably also be used in carrying the new 2,000-pound Demolition Bomb. Some of the new bomb racks which have been designed to replace the old Mark V release mechanisms will be used in the bombing maneuver, and the duty to which they will be subjected should give them a very good service test. Some of these racks are now in use at Aberdeen Proving Ground, and appear to be very satisfactory.

Browning Aircraft Machine Gun

The ground test of the new .50 caliber aircraft machine gun has been practically completed. This gun in ground tests has been fired over 10,000 rounds with only one mal-function. The cause of this mal-function has been corrected. As part of the test the gun was given a freezing test at the Bureau of Standards. For this test the Bureau of Standards developed an oil for the buffer which when used enabled the gun to be fired at minus 20 degrees Fah. It is believed that the gun would have fired at lower temperatures had it been possible to reduce the temperatures in the freezing chamber further, but minus 20 degrees was the lowest that could be obtained. The tests to date indicate that the gun is an extremely satisfactory weapon. Mr. Browning and the Colt Company are to be congratulated on the splendid work which they have accomplished.

Captain Gorton has developed a means by which the new aircraft machine guns being designed can be equipped so that with only slight changes they can be fed from the right hand side, in other words, the

(Continued on Page 295)

SHOT GUN SHELLS

At Cost, Steel Lined, Paper and Brass

12 Gauge

3¼ drams Smokeless Powder, 1⅛ ounces No. 00 Buck Shot

THESE shells will be sold only to bona-fide users, and are not subject to resale.

PAPER SHELLS	BRASS SHELLS
$31.50 per M.	$50.00 per M.

Orders may be sent direct to the Commanding Officer at the Depot or Arsenal at which the shells are located as shown.

Payments and shipping instructions should be sent with order. Payments are to be in the form of certified checks, money order, or bank draft, made payable to the "Commanding Officer" of the Arsenal or Depot from which ordered.

Location of Shells

Columbus Gen. Reserve Depot, Columbus, Ohio.	Paper, Steel Lined	1,000	Remington
Morgan Ord. Reserve Depot, So. Amboy N. J.	Paper, Steel Lined	338,200	Remington
Morgan Ord. Reserve Depot, So. Amboy N. J.	Brass	67,048	Remington
Morgan Ord. Reserve Depot, So. Amboy N. J.	Brass	12,628	Winchester
Raritan Ord. Reserve Depot, Raritan Arsenal, N. J.	Paper, Steel Lined	244,000	Winchester
Raritan Ord. Reserve Depot, Raritan Arsenal, N. J.	Paper, Steel Lined	134,000	Remington
Schenectady Gen. Reserve Depot, Schenectady, N. Y.	Paper, Steel Lined	786,538	Remington
Seven Pines Ord. Reserve Depot, Seven Pines, Richmond, Va.	Paper, Steel Lined	15,000	———
Sparta Ord. Reserve Depot, Sparta, Wis.	Paper, Steel Lined	14,500	———
Wingate Ord. Reserve Depot, Wingate, N. Mex.	Paper, Steel Lined	12,975	———
Woodbury Ord. Reserve Depot, Westville, N. J.	Paper, Steel Lined	14,975	———

WAR DEPARTMENT

"Ordnance Salvage Board"

500 Horsepowe
Complete for Immediate

THE Philadelphia District Ordnance Salvage Board offers for sale by negotiation, Heating Plant No. 2, located at the Morgan General Ordnance Depot, South Amboy, New Jersey.

This material comprises practically a complete heating plant and is ready for immediate delivery. This plant is offered for sale "as is," "where is," removal to be made by the purchaser.

THE ITEMS OF SALE ARE NOT COMPLICATED

An inspection of the plant can be made by applying to the Commanding Officer, Morgan General Ordnance Depot.

Further particulars regarding this plant can be obtained from the

Commanding Officer, Morgan General Ordnance Depot

South Amboy, N. J.

or

Chairman, Philadelphia District Ordnance Salvage Board

1710 Market Street, Philadelphia, Pa.

Negotiations are to be conducted through the Philadelphia District Ordnance Salvage Board

WAR DEPARTMENT
"Ordnance Salvage Board"

r Heating Plant

Delivery

SPECIFICATIONS

500 H. P., consisting of two 250 H. P. Geary water-tube boilers of 244 tubes. Working pressure, 160 lbs., connected with 8-inch mud drums.

Steam drums in battery, 24 inches by 11 feet.

Heating Surface, 5,000 sq. ft. Grate, 7 ft. by 14 ft. by 6 ft. Area, 121½ sq. ft. Hand-fired Acme dumping for No. 3 Anthracite coal.

Two Safety Valves, 4½ inches—each boiler.

One Steam Gauge, 12 inches—each boiler.

One Water Column Combination—each boiler.

One Steel Stack and Breeching, 6 ft. 6 in dia. by 125 ft. high.

Two No. 14 Model N Injectors (Metropolitan). Capacity with 8 lbs. steam, 2 ft.; life, 2,850 gal. per hour; basis, 330 lbs. steam evap. per H. P. hour—400-500 H. P. ordinary type boiler 3300-375.

Two 4-inch Everlasting blow-off valves. 125-lb. Jenkins Bros. 13-inch.

Two 4-inch, 60-degree angle or "Y" type, iron body, blow-off valves, 125-lb. Jenkins Bros. 13-inch.

One 10-inch by 10-inch vertical Watertown engine.

One American Sirocco fan, No. 10.

One Boiler feed pump (Worthington), 9 inches by 5½ by 12 inches, double Duplex outside and packed capable of feeding 1,100 B. H. P. against 160 lbs. with overload. Steam, 1¾; exhaust, 2 inches; suction, 5 inches; discharge, 4 inches.

One Schaeffer & Budenberg revolution counter.

Two 500 H. P. Edge Noor Boilers, second hand. Knocked down and damaged. With necessary headers, pipe valves, etc., not complete.

One Mason Steam Regulator.

One Scale, platform, Fairbanks, 1,500-lbs. capacity.

One Steam Trap, No. 5, Strong.

Four 4½-inch Pipe-flanged safety valves, faced and drilled; 160-lb. Acme Standard.

One Cochrane Feed Water Heater—1,500 H. P., Cochrane heater; depth, 48 inches; width, 56 inches; height, 87 inches; exhaust inlet, 12 inches; cold-water inlet, 2½ inches; pump supply, 5 inches; water and overflow, 3½ inches; vent, 3 inches; trap discharge, 2 inches; 20 trays—21 inches long, 1 inch wide, arranged in two rows. Shell is of cast-iron.

Public Sale by Auction—

Machine Tools, Equipment and Supplies

Located at the United States Army Base, Port Newark, N. J.

Tuesday, Wednesday and Thursday, April 26, 27, 28, 1921, at 10 A. M. Each Day

Machine Tools

Blowers
Crane Parts
Milling Machines
Chucks
Grinders and Grinder Parts
(Gun Boring) Lathes
Cut-off Machines
Textile Machinery
Pumps
Presses
Slogging Saws
Tanks
Grinding Wheels
Motors
Dynamos
Furnaces
Reaming Machines
Metal Saws
Spotting Machines
Hand Milling Machines
Bench Milling Machines
Riveters
Cutter Grinders
Profilers
Polishing Jacks
Thread Millers
Spline Millers
Yarn Reels
Atlas Shredders
Spencer Oilers
Pickers and Feeds
Barrel Reamers
Centering Machines
Stamping Presses
Barrel Grinders
Horizontal Drills
Wood-Working Tools

Miscellaneous Supplies

High-Speed Steel
High-Speed Tools
Pillow and Snatch Blocks
Small Tools
Copper
Bars and Scrap
Brass
Rods and Scrap
Milling Cutters
Reamers
Lathe Parts
Pipe Fittings
Fuses
Gaskets
Gauges
Hangers Shafting
Paint and Oils
Pulleys
Taps
Electric Supplies
Steam-Shovel Parts
Electrical Equipment, etc.

Descriptive Catalogues Mailed Upon Application to the

Philadelphia District Ordnance Salvage Board
1710 Market Street, Philadelphia, Pa.

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Samuel T. Freeman & Company, Auctioneers
1519-21 Chestnut Street, Philadelphia, Pa.

WAR DEPARTMENT

"Ordnance Salvage Board"

Allerton S. Cushman
A. M., Ph. D.
(Ex-Lt. Col Ord., U. S. A.)
In charge of chemical activities and explosive dry houses, Frankford Arsenal, 1917-1918.
Consulting Chemical Engineer and Metallurgist
In charge Industrial Research Laboratories
Reports on metallurgy, coal, petroleum, explosives, dyes, foods, drugs, etc.
1845 B Street, N. W. Washington, D. C.

James A. Drain Dale D. Drain
DRAIN & DRAIN
Attorneys at Law
Wilkins Building, 1512 H Street
Washington, D. C.

Rogers Birnie Wilford J. Hawkins John H. Watson
Birnie, Hawkins & Watson
Ordnance and Industrial Consulting Engineers and Accountants
511 Fifth Avenue New York

(Continued from Page 290)

guns can be fired either right or left hand and be interchangeable in right and left hand mountings with only a slight change in the mechanism each time the shift is made. It is proposed to supply the necessary parts with each gun so that the guns can be mounted either right or left hand, as desired. These features will be taken up in the model 1919 gun, probably in the .50 caliber, and in the new .30 caliber aircraft machine gun, which it is proposed to develop.

Request for Historical Data

The Engineering Department of The National Acme Company at Windsor, Vt., is engaged in writing a complete history of the rather surprising mechanical developments of this country town during the last hundred years.

One of the most famous concerns which existed there was the Robbins & Lawrence Company (1848-1858), Armorers and Machine Tool Builders. This concern built thousands of muskets and rifles for the United States and foreign governments, and developed the interchangeable Enfield Rifle. The British Small Arms Commission visited the Windsor Armory in 1853, and ordered there the greater part of the machinery for the new Royal Armory at Enfield, England. Maj. Alfred Mordecai, of the U. S. Ordnance Department, reported after his visit to England in 1856 that "* * * the names of 'Ames' of Chicopee, Mass., and 'Robbins & Lawrence' of Windsor, Vt., are accordingly to be read on most of the machines at Enfield Armory, and are constructed in a style highly creditable to the skill of our workmen."

Robbins & Lawrence perfected the 20-shot Jennings rifle (the ancestor of the Winchester), in 1850, and there were invented at their plant the Howe Miller (now called the "Lincoln" Miller) and the Turret Lathe. They also built the famous Sharps Breech Loading Rifle at their plant in Hartford, Conn. During the Civil War the Windsor Armory, under Lamson, Goodnow & Yale, turned out nearly 50,000 rifled muskets, 1,000 Palmer Breech Loading Carbines, and 1,000 Ball Repeating Carbines for the U. S. Government, besides a great number of machines for other armories.

Numerous well-known concerns of the present day have directly descended from the Windsor Armory, among these being The Jones & Lamson Machine Company, The National Acme Company, The Sullivan Machinery Company, and The Billings & Spencer Company; and all this goes to prove what an important part the old-time contract gun shops have played in the mechanical development of the United States.

As it is rather hard to gather all the facts from the dim past, the writer feels that he is overlooking important information in connection with this work which may be known to some of the readers of ARMY ORDNANCE. He will therefore welcome such information or suggestions, and will give credit for anything which proves to be of value to the work.—*Guy Hubbard, The National Acme Co., Windsor, Vt.*

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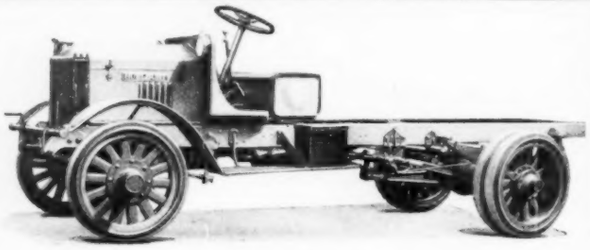

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Motorized Combat Transport

By

LUCIEN B. MOODY

Member A. O A.

"I am building secure and covered chariots which are invulnerable, and when they advance with their gun into the midst of the foe, even the largest enemy masses retreat, and behind them the foot soldiers can follow in safety and without opposition."—*Leonardo da Vinci to the Duke Sforza, 1492.*

"Tanks must then be recognized as a purely offensive arm, developing and possessing powerful means to help the infantry in its supreme mission, the attack, penetration and occupation of ground."—*Tactics and Technique of Tanks, General Service Schools, Fort Leavenworth, 1920.*

THE principles of tactics or the handling of troops in the immediate presence of the enemy have been developed through the centuries, and change so slowly, that Leonardo da Vinci, if alive to-day, would have no trouble in understanding the tactical function of the modern tank. This does not mean that military services are hopelessly conservative. It simply means that it requires about the same length of time for a new invention to definitely affect military tactics that it does to establish itself in the civilian community. Considerable apparent misunderstanding as to why certain things are not done by magic in the military service would be avoided if it be remembered that human nature is not changed by military service.

Colonel Moody

There are about the same difficulties in educating the inventor to the needs of the user and the user to the possibilities of the new inventor, in financing, correcting preliminary mistakes, overcoming prejudices, using up the old material on hand, and finally developing refinement of details as a result of use. Most of us can remember the time it took for the radio, the automobile and subway to become developed to serve our every-day needs. About the same length of time was required for smokeless powder, modern field guns, submarines, etc., to become really effective in the military service. Mechanical transport must also serve its apprenticeship.

By cross-country transport is meant means of transport which may be utilized independently of roads, and for combat transport in the military service everything is subordinate to the ability to go any place a man can go irrespective of terrain or weather. In difficult commercial service, such as mining and logging operations, ability to function where ordinary vehicles will not function is essential, but reasonable concessions may be made to the weather and other local conditions.

Therefore, in judging the reasonableness of military requirements, it must be borne in mind that the equipment intended for battle must not fail at the critical moment due to accidents or weather or terrain, and, if necessary, the material must be designed for the exceptional case rather than the usual. In any other service a day or so lost, due to weather, is merely an inconvenience and is really an economy, provided the vehicle used performs more efficiently or economically on other days than a vehicle capable of operating on the occasional bad day.

"General Capper explained that the British commanders were convinced that *in order to make a rapid advance the forces must be supplied with some sort of cross-country mechanical transport. Experience had shown that an advance was generally brought to a standstill owing to want of supplies.* The importance of having some arrangement to get wheeled transport across country was fully recognized. It was thought that the general question of the supply of cross-country mechanical transport was closely connected with the question of fighting tanks. General Estienne had then rightly remarked that this was a question which belonged to the artillery, but that he would point out that all these questions relating to the carriage of infantry and carriage of munitions, supplies, etc., were closely connected and the more uniform the type of vehicle obtained, the better it would be. *He was convinced that no army could be complete, no army could exploit success, unless it was made independent of roads.*" (Extract from minutes of meeting of June 5, 1918, Inter-Allied Tank Committee.)

As the result of the perfection of self-propelled motor vehicles and the creation of the great facilities for their manufacture in the preceding decade, cross-country transport had begun to be effectively developed in the United States about the time the War started, and in the motorization of artillery the United States has decidedly led other countries, even to the extent of motorizing a large percentage of divisional artillery in the midst of war over the active opposition of allied officers. It is not believed that the proposition was really sold to our allies until about the date of the above quotation from the minutes of the Inter-Allied Tank Committee.

It is the purpose of this article to relate briefly the efforts of the past and present to co-ordinate military requirements with commercial developments, and to discuss some of the broader aspects of the ultimate possibilities of commercial developments that will be of real use in the military service. In other articles in this issue there are discussed the elementary technical requirements of cross-country transport, the special military features in so far as artillery is concerned, and strong arguments for prompt and extensive development for everyday use in peaceful pursuits.

Reconnaissance Tractor
Preliminary model of vehicle designed to replace the individually mounted man

In arriving at a logical conclusion it is necessary to trace both the trend of military and commercial requirements and the actual physical development of equipment to determine whether military requirements and commercial equipment are approaching or diverging.

The first experiments in adopting motorization to combat uses were quite naturally made with the conventional rear-wheel drive trucks, the first official attempt with which the writer is familiar being a motor "Battery wagon" or machine shop mounted on a special chassis by the Ordnance Department in 1904 and tested out in connection with regiments of horsed artillery. Many other experiments were made with these vehicles from time to time, and so far as the artillery and ordnance were concerned always resulted in an adverse decision, but the most definite statement of policy on the part of the War Department regarding two-wheel-drive trucks is the following, extracted from the Westervelt Board report, which was approved by the War Department in June, 1919:

"In the opinion of the board, the four-wheel-drive, two-wheel-steer type of truck is the only heavy cargo-carrying wheeled vehicle which is adequate to meet artillery needs in the battery, battalion and the regiment, as well as in the artillery ammunition train, and until definite recommendation to this effect is approved, artillery will be burdened with a heterogeneous mass of trucks whose use is confined almost entirely to good roads."

About ten years ago various trucks driving on all four wheels began to come on the commercial market, and various makes were tested to see whether they were equal to the horse for cross-country work. It was found that these trucks had a very considerable capacity for off-the-road work, as well as ability to operate as ordinary trucks on good roads, and in the absence of other than low-speed tractors they were adopted in the artillery service as a valuable auxiliary to other vehicles, and at the present time are still standard truck equipment in the artillery service. The following extract from report of the Field Artillery Board, December 7, 1915, on the test of several makes of four-wheel-drive trucks is an official statement of their limitations:

"The ——— truck is suitable for ammunition service but not for economical or trustworthy traction off roads. Under easy conditions trucks may be used to handle light tows, but under what may fairly be called ordinary difficulties

Fully loaded

they are not equal to the horse draft, and even the addition to their equipment of winches carrying wire rope, although this would add greatly to their power to overcome many obstacles, can not be expected to obviate the disastrous delays that this kind of draft will meet in column at bad fords, on steep grades or on soft roads. This fault can not be overcome by the installation of more powerful engines alone because failures in traction appear to be due to lack of necessary friction with the ground."

The Chief of Ordnance concurred in the findings of the Field Artillery Board as follows:

"The conclusions of the Field Artillery Board in regard to the use of the four-wheel-drive trucks for tractive purposes have been noted and are in agreement with the conclusions reached by this office as a result of tests conducted at the Rock Island Arsenal."

In due order various wheeled tractors of both the two-wheel-drive type and four-wheel-drive type were tried, but always with the result that they were not felt to have the certainty of getting there essential to hauling artillery into battle.

Climbing small embankment

The Army definitely became committed to the track-laying or caterpillar tractor for artillery as a result of report of the Field Artillery Board of December 7, 1915, which contained the following on the operations of such a vehicle:

Crossing ditch

"The tractor was never in difficulty on these hard climbs or in these bad crossings. From A to B are two cattle guards, a railroad bridge with one tie gone and a trestle; at B is a difficult turn; at C is a very crooked ford with sandy steep approaches; at D are very steep banks in V-shape; at E are sand and gravel. On the other route shown were considerable stretches of sand and loose cobble stones; at F two narrow channels about three feet deep; at G a washed-out bridge over a spring branch, necessitating going over a bank and mud-covered ledge. The remarkable features of this route were the difficult grades and bad footing."

The Board had before it the reports of all tests at Rock Island Arsenal, and an Ordnance Officer was sent to Fort Sill at the request of the Board to insure co-ordination between the results of the Fort Sill and Rock Island tests.

The first positive approval of the track-laying tractor for use in divisional artillery was given when the question of motorizing the 155 mm. howitzer materiel was considered after the entry of the United States into the war. The report states:

"The Board is of the opinion that the 50 H. P. tractor, weighing approximately 8,000 pounds, completely demonstrated without question its superiority over animal transport in all the tests made.

"In the rough-ground test the tractor showed that it can take its load over terrain so rough and broken as to be virtually impossible for horses to negotiate.

"It is not believed horses could have pulled the load through the mud hole in the soft-ground test nor up the slope encountered in the last test."

(Report board convened by S. O. 242, Par. 69, W. D. 1917, Nov., 1917. History file 467 T. T. T. Div. O. D.)

Up to the present time the track-laying vehicles used have been essentially adaptations of types primarily designed for farm work, and the effort of the ordnance engineer was primarily concentrated on minor improvements found necessary in the Military Service, and in the case of vehicles intended for light field guns to provide an emergency speed corresponding to the gallop of the horse, which while destructive to the older types of mechanisms if long continued, was not seriously injurious to these mechanisms if the speed was used with discretion. The World War, however, has many examples of infantry being moved long distances in motor trucks and going into battle at the end of a journey without the support of its horse-drawn or motor-drawn artillery or having to wait an unreasonable time for the arrival thereof, which has resulted in a new demand that motorized combat vehicles be able to maintain continuously speeds of 10 or 12 miles per hour, corresponding to the speed of a convoy of trucks, in order that the infantry may not lose touch with the tanks and artillery whose support it should have when moving into action. At the same time these vehicles must not in any way compromise their ability to function over any sort of ground that a horse or man may cross. It is obvious that, while the underlying principles may not be affected, radical changes in the details of construction of the early vehicles must be made if this new condition is to be successfully met.

Through quicksand

Another point on which there is some controversy is whether the present standard tractor-drawn guns should be replaced in whole or in part by guns actually mounted on motor vehicles. The following is believed to be a fair statement of the relative advantages of each method:

Weapons up to and including 4.7-inch gun and 155-mm. howitzer

Advantages of self-propelled system. Less cargo space in rail and sea shipment; less road space; rapidity of going into position; rapidity of withdrawing from position; smaller turning radius; no digging necessary for trail spade; ability to obtain quickly all-round fire by moving whole mount.

Disadvantages of the self-propelled system. More difficult to conceal; one direct hit or mechanical defect disables both gun and its transport; increases the number of types of special motor vehicles; violates principle of keeping weight of tactical vehicles at a minimum; the self-propelled unit weighing almost twice as much as the tractor or the gun which it hauls; when in firing position the transport can not be employed for other useful purposes or conveniently repaired.

Heavy Weapons

The principal feature is the facility with which the heavy weapons using the self-propelled system can go into action, open fire, and move to another position, thus making the counter-battery work of the enemy more difficult. The same

The amphibious tractor

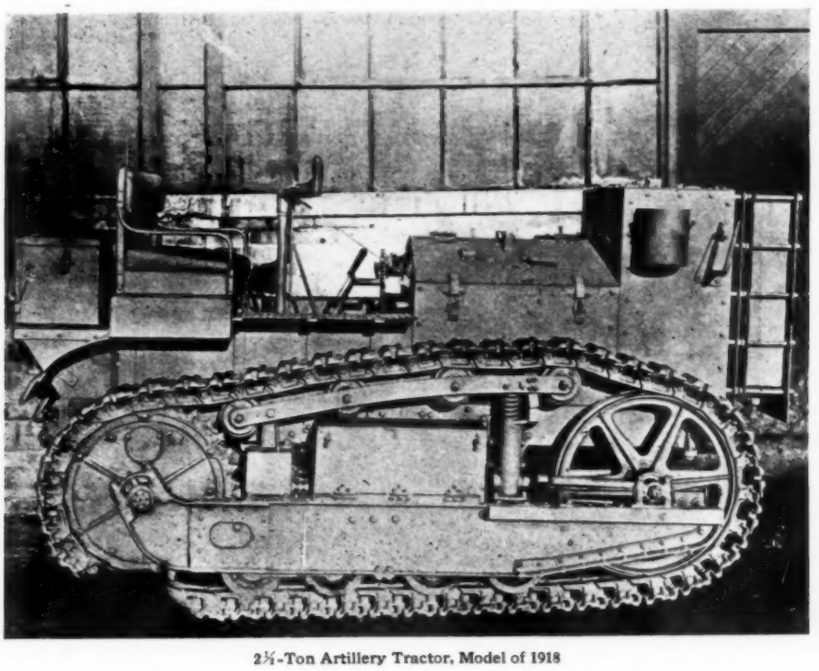
weapon using the tractor system usually comprises several transport loads and requires a comparatively long time to assemble for firing. The main disadvantage of the heavy self-propelled mounts is the great concentrated weight.

While the ideal solution is to use for combat transport purposes vehicles which are actually used in commercial life in time of peace, there are at present in commercial use no vehicles which are entirely satisfactory and few that are sufficiently satisfactory for emergency use.

It has, therefore, been considered advisable by the War Department to design and build experimental vehicles which would meet military requirements with the idea that these would be available for production. In cases such as tanks, where there is little hope of ever using commercial vehicles as sold on the market, and in other cases such as tractors, where the commercial article is still in the development stage, it is felt that the advanced models gotten out by the War Department will be of real assistance to commercial developers in determining whether or not similar commercial developments would pay.

Tractor Power Cart

In designing the government vehicles every care is taken to use commercial parts if possible, and if not, to use approved commercial materials, tolerances and shop practices



2½-Ton Artillery Tractor, Model of 1918

so that the vehicles could be produced if necessary with the minimum amount of disturbance of existing plants.

The following observations are, however, made with reference to *commercial* vs. *government* design:

(a) If commercial industry, including commandeering of vehicles from civil life, can supply from existing factories in a reasonably small number of models the vehicles necessary for any particular purpose, the supply problem is solved.

(b) If only one or two factories are producing a satisfactory article in quantities insufficient to meet war demands, and if there are in these models components such as engines built for these vehicles only, it may be easier to put in general production in several plants a government designed vehicle using a commercial engine and other parts which are already in sufficient production.

(c) Experience in this war showed that in many cases commercial plants making specialized articles did not have their drawings, etc., in shape for ready transposition to another factory, and in some cases actual production of new government designs was obtained more quickly than production of commercial designs in new factories.

(d) The use of government designed parts, such as engines, differentials, clutches, universal joints, etc., is believed to be an absolute mistake where suitable commercial parts are available. It should be borne in mind that in using parts designed by various people the government in war is not handicapped by consideration of patents, commercial pride, or business policies which are frequently controlling reasons in civil life.

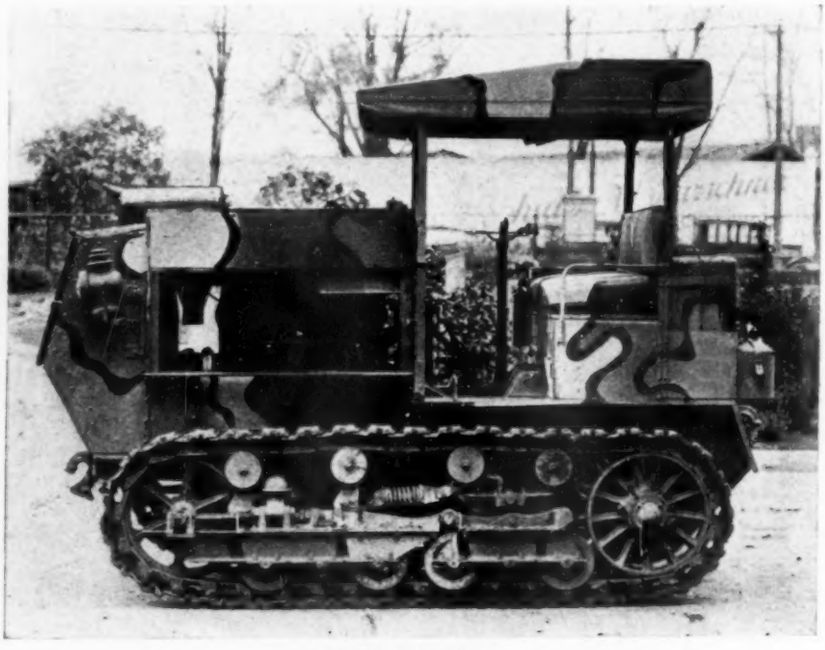
(e) Experimental vehicles built by private concerns which are naturally assumed to largely use commercial parts are often far more special from the standpoint of large production than a government designed vehicle.

In the matter of combat motorization a most consistent and successful effort has been made from the start to keep commercial industry, the General Staff, the using service and the Ordnance Department in co-ordination. Previous to the war this was accomplished by informal conferences, the first formal action being a request of the Chief of Ordnance dated April 13, 1917, for a board to consider all questions relating to the motorization of artillery. At his suggestion, the War Department included the President of the Society of Automotive Engineers on the Board. Since then there has not been a day on which there was not in existence a duly constituted agency to co-ordinate all interested parties, the war-time agencies being special boards and the present agency being the Ordnance Committee, which has available the expert civilian advice of the Advisory Committee of the Society of Automotive Engineers. It is the personal belief of the writer that the smooth working of the various boards to consider artillery motorization during the war was the direct forerunner of the present Ordnance Committee and he is certain that the operations of these Boards were a controlling influence in deciding the Society of Automotive Engineers to appoint its Ordnance Advisory Committee after the war.

2½-Ton Artillery Tractor, Model of 1920

Considering the length of time that must elapse before the United States is amply equipped with good roads, the great damage done to our roads by heavy wheeled vehicles, the legal limitations on axle loads and the undoubted opportunities for increasing the life and speed and decreasing the maintenance cost of track-laying vehicles, it is believed that great improvements must be made in commercial track-laying vehicles and that their commercial use should be considerably extended.

It is believed that the Ordnance Department must continue its present development of these vehicles to meet military requirements but it is to be hoped that, as a result of continuing the present policy of having all Ordnance designs checked from a production standpoint by the Ordnance Advisory Committee of the Society of Automotive Engineers, Ordnance designs will either be adopted by commercial organizations or new commercial designs will so nearly meet military requirements that in the comparatively near future there will be in commercial use vehicles which with slight changes will be available for war.



5-Ton Artillery Tractor

Col. Lucien B. Moody, author of the above article, was, in July, 1905, detailed in the Ordnance Department for station at the Sandy Hook Proving Ground. Later he served at the Watervliet Arsenal and the Manila Ordnance Depot. During his second detail he served at Sandy Hook Proving Ground, and two years in the Gun Division of the Ordnance Office.

After a year's tour of duty with the Coast Artillery, he was stationed for two years at Rock Island Arsenal where he began to specialize in motor equipment. Upon the outbreak of war he was ordered to Washington and appointed Chief of the Motor Equipment Section, charged with the design, production, and inspection of all motor transportation and accessories furnished by the Ordnance Department to the enlarged army. In June, 1918, he was ordered to France, and handled similar questions in the Office of the Chief Ordnance Officer, A. E. F., and was a member of various boards considering such matters until he was appointed Ordnance Officer, Third Army (Army of Occupation in Germany), at the signing of the Armistice. On his relief from this duty he was returned to the United States and reappointed Chief of the Tank, Tractor and Trailer Division.

Homogeneity of Field Artillery Motor Equipment

By

W. A. CAPRON

Member A. O. A.

THE basic problem in motorization of mobile artillery is to provide a means of transport that will permit this combat agency to successfully march and manœuvre over cross-country terrain. While the problem is reasonably well solved by insuring the movement of the guns and ammunition, it is not completely solved, in the case of divisional artillery at least, until all the elements of the combat units can manœuvre with uniform certainty and uniform speed.

Another important object to be obtained is to have units, all the elements of which can move at uniform speed on the roads, these speeds varying from 2 or 3 miles per hour behind marching infantry to about 12 miles per hour when accompanying infantry loaded in motor trucks.

The advantages of having standardized equipment from the standpoint of ease of supply, decreased variety of spare parts, etc., are too well known to need discussion here.

At present the track-laying vehicle is the accepted means of transport for guns and the initial supply of ammunition, but mixed with such transport in our organizations are light and heavy trucks, touring cars, motorcycles, caissons, wheeled anti-aircraft machine-gun trailers, motor ambulances, rolling kitchens, wire reels, etc.

In justice to the Army it must be borne in mind that due to the limited development of suitable vehicles before the war and the necessity of using any suitable materiel available during the war, it has been impossible until very recently to attack this problem as a whole, and before suggesting possible solutions a brief review of the steps that led to the present equipment may be of interest.

The first track-laying tractors had a speed of about 3 miles an hour, which was insufficient for transport of other than the minimum materiel that must be gotten into position with certainty to start the action, and so reliance for the greater part of the combat transport was placed on four-wheel-drive trucks which, under favorable conditions, could also move the guns into action at greater speed than the tractors. The board that recommended this combination in 1915 was fully aware of the objection to dual means of transport, but it was the best available.

A few horses were retained for the use of battery officers and fire-control personnel. Due to complications of supply, the horses were soon replaced by motorcycles and touring cars, but these introduced new complications in the way of different speeds, variety of spare parts, etc. The other varieties of equipment are largely the result of using what was available during the war or hurriedly adapting to motorized artillery equipment that was originally intended for horsed organizations.

In considering what can be done to simplify the present transport situation, it is necessary to consider both the transport of guns and ammunition, which is so vital that no substitutes for satisfactory materiel can be considered, and the transport of the less vital equipment in which concessions can be made if necessary.

The motor-driven track-layers, whether in the form of tractors, self-propelled gun mounts, or tractor caissons are all giving promise of being able in the comparatively near future to maintain the speed of trucks on good roads without sacrificing any of their cross-country ability, and new gun carriages are being provided with springs and rubber tires, so that they will be able to stand the speeds of the tractors. From present studies of the more advanced vehicles of new design it appears that the tractor can be made to carry a reasonable amount of condensed cargo, thus making the tractor and the tractor caisson one and the same vehicle. The replacement of the caisson, or special ammunition carrier, by the trailer caisson (caterpillar trailer) already has the sanction of the War Department, and this vehicle should, of course, use as far as possible the parts of the tractor with which it is pulled.

Should the replacement of gun-carriage wheels by caterpillar tracks be decided on as the result of service tests of these units, it should be possible to use practically the same tracks as are used on the trailer caissons. The trailer caissons can be used for the transport of gasoline, repair facilities, reserve rations, field kitchens, and, in fact, everything essential for the operation of an artillery organization except the transport of individual men. For this purpose the reconnaissance tractor, which is a small track-laying vehicle intended to carry two men, is being developed with promise of ultimate success.

While all of the new vehicles referred to are still in relatively early stages of development, and none are yet ready for service test, sufficient has been learned so that it may be confidently stated that it is mechanically possible to completely equip an artillery regiment with track-laying materiel, using a single type of track for its heavier materiel and the reconnaissance tractor for individual men and observation instruments.

Whether this ideal condition would be realized in war is probaby dependent upon the extent to which the vehicles involved are commercialized. If the complete vehicles or their major parts are commercialized, complete equipment of the approved types could be expected. If the vehicles are largely special, probably no more than equipment for the firing battery could be expected in the early stages of a war, and commercial trucks and touring cars would be supplied for other purposes.

However, preliminary experiments with the Chase type of track for commercial vehicles indicate the possibility

of being able to quickly convert these vehicles into track-layers that would be able to follow the organization at its marching speeds either on or off the roads and still insure to the commander a homogeneous manœuvring unit.

15-Ton Artillery Tractor

Discussion by Maxwell Murray

Major, Field Artillery

It is felt that the principles stated in the above article are basically sound. Particularly is it true that Divisional Artillery must be prepared to meet the demand for both strategic and tactical mobility which will enable it to accompany its divisional infantry when moved in trucks, and which will make capable of moving forward over broken terrain at a rate which will insure continuous infantry support by its fire, this continuous support being accomplished by advancing units of the artillery by echelon as the infantry progresses beyond the range of the guns in their first position.

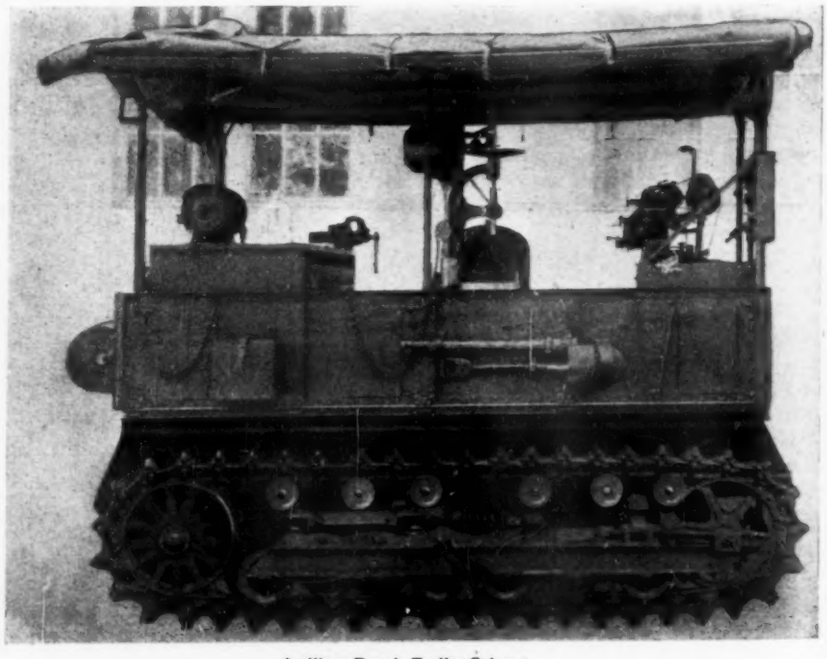
It is accepted that to date the only satisfactory demonstration of the tactical mobility required by motorized light artillery has been by track-laying vehicles, and it appears that some form of this mechanism is necessary to give motor vehicles ability to progress off the roads.

On the other hand, the wheeled vehicles appear to possess a decided advantage over track-laying vehicles for operation over good roads, and it is possible that the requirements for strategical mobility will cause the adoption of this mechanism for movement where roads permit. It is recognized that in the effort to develop the combination of strategic and tactical mobility remarkable advances have been made both in improvement of track-laying vehicles and in the combination of wheeled and track-laying mechanisms by applying an easily detachable tread to a specially constructed wheeled vehicle.

At the present time, the Field Artillery is absolutely open-minded as to the ultimate type of transport for the guns and ammunition vehicles. Performance and demonstrated reliability must be the determining factors, and it is felt that we are now on the threshold only of satisfactory motorization.

Regarding the desirability of Homogeneity of Motor Equipment in the ideal organization there can be no question, and it is believed that the problem and its practical solution are well covered in the preceding article. Unfortunately for the realization of our ideal, it seems logical to assume that as road conditions throughout the United States improve, the demands for "tactical mobility" of commercial vehicles will be modified. If this be true, the difference between the military demands and the commercial necessities will probably be emphasized, with the result that the ideal equipment for artillery will be more specialized than ever.

However, it is believed that the ideal of standardization can be gradually approached as our present equipment is eliminated and that the efficient maintenance with corresponding increase in the efficiency in performance will lead to the answer to the demands for mobility of motorized artillery.



Artillery Repair Trailer Caisson

Compilation of War Specifications

By

E. H. CHASE

Member A.O.A.

UPON the adoption of motorized vehicles as standard equipment of the Army it became necessary to compile specifications covering not only the vehicles themselves in a general specification, but specifications covering the component parts thereof.

As practically no work of importance had been done along this line up to February 2, 1918, except that urgently necessary in connection with contracts, there was established on the date mentioned in the Motor Equipment Section, Engineering Bureau, Ordnance Department, the first separate Specification Unit of record in the Ordnance Department. The work assigned to this unit was solely the compilation of standard specifications of the Ordnance Department for tanks, tractors, trailers, bodies, loads and accessories.

In order to properly compile these specifications it was obvious that the personnel performing the work should be those with a thorough knowledge not only of automotive engineering but also metallurgy and related sciences. As little attention had been given to this matter by the personnel of the army prior to this time, reserve officers and civilians formerly affiliated with the automotive industry were drawn upon to complete the organization of the Specification Unit.

The Office Order establishing the Specification Unit specified the duties assigned thereto as "To prepare and keep on record complete specifications of every item of equipment which comes under the Motor Equipment Section" and "To revise specifications in accordance with corresponding revisions in design."

Before it was possible to initiate the compiling of standard specifications, it was necessary to classify and card index such outline specifications as had been compiled before so that duplication of work would not be performed. As these outline specifications were in the main too brief for practical use, it was necessary to rewrite a large majority of them, which work required some little time of a portion of the personnel, while the time of the balance of the personnel was occupied by perfecting the organization of the unit so as to perform the vast amount of work before it in an efficient manner.

Some idea of the magnitude of this work can be gotten when it is considered that it was roughly estimated there were approximately 150,000 separate specifications to be written covering the general specifications of the vehicles themselves, specifications of the component parts thereof, bodies, loads and accessories. Even as simple an article as a spare part required at least a name, a drawing number and the maker's number.

The fact must not be lost sight of that, in addition to the writing of the specifications, preparations were necessary for the proper filing and recording of the complete specifications, also for their distribution. After this work had been started, it was soon apparent that additional duties would have to be assumed by this unit in connection with the affiliated information on various subjects which arose in the natural course of events. This included for a time the handling of procurement requests, work orders, the compilation of estimates of the quantity of various metals and non-metals used in the Ordnance Department, which information had to be secured through extensive correspondence with manufacturers to whom contracts had been let for the respective material.

To correctly specify each item, considerable research work was necessary, as were also many conferences with the other sections of the Engineering Bureau and with the other Bureaus and Divisions of the War and Navy Departments. This research work was also inevitable from the standpoint of co-ordination and standardization. In this latter connection additional duties were assigned to the Specification Unit by establishing as part thereof a Standardization Unit, as the policy of standardization of motor equipment as far as possible was not only a logical but necessary economy.

As each specification was referred to and made a part of each contract placed by the Ordnance Department, a

Mark VII Tractor Caisson

standard specification form was therefore adopted.

To insure accuracy so as to preclude any controversies, either verbally or legally, should material manufactured thereunder be rejected, these specifications before the final approval of the Chief of Division were checked by four different members of the personnel.

Tractor Caisson crossing Ditch

In order to assist the personnel of the unit in writing specifications and also for the use of the engineers and draftsmen of the Ordnance Department there was established and maintained a file and library of manufacturers' catalogues and technical books, the numbers running into the thousands. This library soon became a source of engineering and procurement information of inestimable value to the War Department.

Upon the signing of the Armistice and the suspension of manufacture the Specification Unit practically ceased to exist, and subsequently the compilation of specifications became the duty of a special Specification Board appointed by the War Department. However, each Manufacturing Division of the Ordnance Department is required to compile the general specifications covering its respective materiel, using as far as possible the standard War Department specifications adopted by the Specification Board. The work has been greatly facilitated by the plan adopted of specifying the respective material specifications on the drawings themselves, which obviates the necessity of compiling separate specifications for each component part of a motorized vehicle. Therefore, in the future, instead of the necessity of compiling and revising approximately 150,000 specifications it will only be necessary to compile and revise the general specifications covering the vehicle itself, its body, load or its accessories, changes in the specifications of the component parts being taken care of by the revision of the drawings.

The Library Section of the Specification Unit is still maintained as the information contained therein is exceptionally valuable to the Ordnance Department.

Trucks, Tractors and Trailers

The preliminary design of a 2-ton crane for the 5-ton tractor has been initiated.

The test of one preliminary cylinder for an air-cooled tractor engine at Syracuse Engineering Office, is 80 per cent completed.

The detailed drawings showing the application of the Chase fabric track to the Militor truck are completed.

The Ford chassis fitted with Chase fabric track has been run 1,485 miles, and the fabric track still in good and serviceable condition.

The design of the ¾-ton trailer is completed, and the detailed drawings being checked and orders for manufacture placed.

The Chase fabric track is also being fitted to Reconnaissance Tractor, Peoria design.

The study and test of forged steel track shoes for Artillery Tractors have been completed. Three types have been tested and all proved unsatisfactory.

Artillery Tractor hauling 155-mm. Gun

A large number of parts pertaining to the 2½-ton Artillery Tractor, Model 1918, has been declared surplus and inventory forwarded to Ordnance Salvage Board.

Cross-Country Vehicles as an Essential Future Development

By

LEWIS K. DAVIS

Member A. O. A.

THERE is probably no truer saying than Napoleon's statement that "An army travels on its stomach," for it must have food for its men, food for its animals and food for its guns.

When the Germans made their advance south of Rheims towards Chateau Thierry, they covered approximately 34 miles in four days. They were blocked not by any real determined defense, but through the fact that they had lost contact with their supplies. This was also true in the retreat of the Somme, for when the Portuguese gave way, there was a lane five miles wide in which there were no French, British nor Portuguese soldiers to oppose the German advance.

Since the close of the war there has been continual fighting in various sections of Eastern Europe. A careful study of the maps of the operations of General Deniken shows that in no instance was it possible for him either to keep in contact with his supplies, or to consolidate his positions in the rear. Invariably his flanks were unprotected. If the reports which come out of Anatolia are true, the failure of the Greeks to control their supplies has recently caused a severe defeat of the Hellenic Army by the Turkish Nationalists.

Failure to keep contact with one's base of supplies is due to two causes:

1. Lack of railroad transportation.

2. Lack of road capacity, which is immeasurably increased if the roads have been previously shelled.

How this is to be overcome in a warfare of rapid movement is a problem confronting the staffs of all the armies of the world. At the present time there seem to be but two solutions, neither of which is yet perfected—namely, the aeroplane and the cross-country vehicle.

The present limited carrying capacity of aeroplanes makes their use negligible in any large operation, but owing to the rapid strides made in the last five years it is impossible to prophesy what the future will develop in this branch of the service.

The other possibility is the cross-country vehicle. Owing to the picturesque interest created by the aeroplane, unless great perspicacity is shown, larger sums of money will be appropriated for development of aerial transport than for the less spectacular cross-country vehicle. In the end, we may find it to be a case of "The Hare and the Tortoise."

In 1915 the first tank, called the "Little Willy," was invented and built in England. Its maximum speed was two miles an hour. In 1916 a British Mark IV tank made its initial performance, its maximum speed was 6 miles an hour. In 1918 the British "Whippet" medium mark "A," displaying a speed of 12 miles an hour, was brought out. In 1919 the medium mark "D" developed a speed of 21 miles an hour.

Thus in four years the cross-country vehicle has shown the remarkable speed development of from 2 miles to 21 miles an hour. The designers of the mark "D" even prophesy a speed of 30 miles an hour for their tank, and, from latest information, it is able to make 15 to 20 miles over plowed fields, crossing 11-foot trenches and carrying one 6-pounder and four machine guns, with a complement of 6 men.

The original "Willy" and the mark "IV" required four men to drive them. These were distributed as follows: two gearsmen, one brakeman, one tank-driver. In 1918, this was reduced to one man, who had, however, to use both hands and feet. The driving was so laborious that four hours steady driving was the limit of endurance.

In the 1919 machine perfect control is had through a hydraulic mechanism which can be controlled by two fingers of one hand. This represents the development to date of the tank, for war purposes, so far as is known.

In the commercial field we have only the farm and heavy tractor, with its speed of from two to four miles an hour, which, for the purpose for which it is intended, does the work more or less satisfactorily, and for this reason, up to the present, no development of a vehicle of the cross-country type, adaptable to commercial carrying purposes, has been made. Nevertheless, those who pay road taxes are slowly waking up to the fact that they are being swamped with taxes for repairs to roads due to damage caused by a combination of road pressure per square inch, and speed, in the heavily loaded wheel-vehicle type of heavy carrier. Already, in Arkansas, property has been taxed four times its sale value for road construction, and this without provision for up-keep.

On this account almost every state is passing laws limiting the road pressure of vehicles, and the ultimate result will be to force development of the cross-country vehicle, not necessarily because of its capacity for cross-country traveling, but because of the fact that with even a speed of from 15 to 20 miles an hour the impact is practically *nil*, while the road pressure will be about 5 per cent of that of the ordinary wheel vehicle carrying equal load.

In speaking of a cross-country vehicle for the above purposes, I have in mind a machine entirely different from the ordinary tractor with its incapacity for carrying any load. What is required is a machine with a standard chassis, which in time of peace can have all the various types of carrying bodies fitted to it, and in time of war can be quickly modified into a gun carrier, an armored car, infantry carrier or supply wagon, able to turn in its own length, and having track shoes with rubber inserts in contact with the ground. This machine is certain to come as a war development, but may well be developed for peaceful uses, and this peace-time development will be forced should all

the states limit the unit pressures of axle loads of vehicles using the roads.

The amount now appropriated for experimental purposes by the Government is entirely inadequate to accomplish any real development of such a vehicle. Some time, however, the "houses of slumber" will wake to a realization of the relation of the truck to the taxes, and it will be evident that an expenditure now of $25,000,000 for development of a roadless vehicle would pay for itself in ten years in saving of the money spent in the upkeep of roads.

Self-Propelled Mount for 75-mm. Gun

At the first the tank as a cross-country vehicle was treated as a joke, later it was tolerated with amusement. Finally, it incurred violent opposition. So far as the army is concerned this came almost entirely from two sources:

First, through the use of the tank by those who, having no knowledge of its limitations in its early form, tried to order it through places which it was incapable of negotiating; and second, the opposition of the cavalry, who can not be much blamed, as the final development of the tank will sound the death knell of the cavalry as a fighting arm. Under the future methods of warfare, be it a great or a small war, or even simply a riot call, the cavalry will have no place. Its work will be taken by the cross-country vehicle, having an average speed of 15 miles an hour, with a radius of action of say 200 miles. This is no longer a conjecture, it is a fact. These machines have already passed the stage of either possibility or probability. In less than three years they can be made commercially perfect, provided the same amount of money is used in their development as will be used in refining and developing the aeroplane.

For war purposes, cross-country vehicles can be divided into sections as follows: Tanks, artillery mounts, ammunition carriers, water carriers, infantry and infantry supply carriers, ambulances and operating rooms, and miscellaneous vehicles for specialized services.

We are all familiar with the functioning of the cross-country vehicle as a tank and artillery mount. We may therefore pass to cross-country vehicles as ammunition carriers. The new English cross-country transport wagon is capable of making 20 miles on the road, and half as much across country, while carrying a maximum of 10 tons, exclusive of the weight of the vehicle.

The pack-horse as used under bad conditions on the English front carried 8 rounds of 18-pounder or 4 rounds of 4.5-inch ammunition. The expenditure of one 18-pounder or a 4.5-inch gun during one battle day is approximately 400 rounds. To supply this necessitates the use of from 50 to 100 pack-horses per gun or howitzer. Counting various delays and "rests for watering and feeding, the forward journeys in the last war were rarely made under 12 hours, and more frequently took 18 hours." One transport wagon with a capacity of 10 tons would be able to handle 800 18-pounders, 450 4.5 howitzers, 250 60-pounders or 200 6-inch howitzer shells, which means that one of the transport wagons referred to would do the work of 112 pack-horses.

Mark VIII Tank

Second, infantry supply carriers and the infantry car-

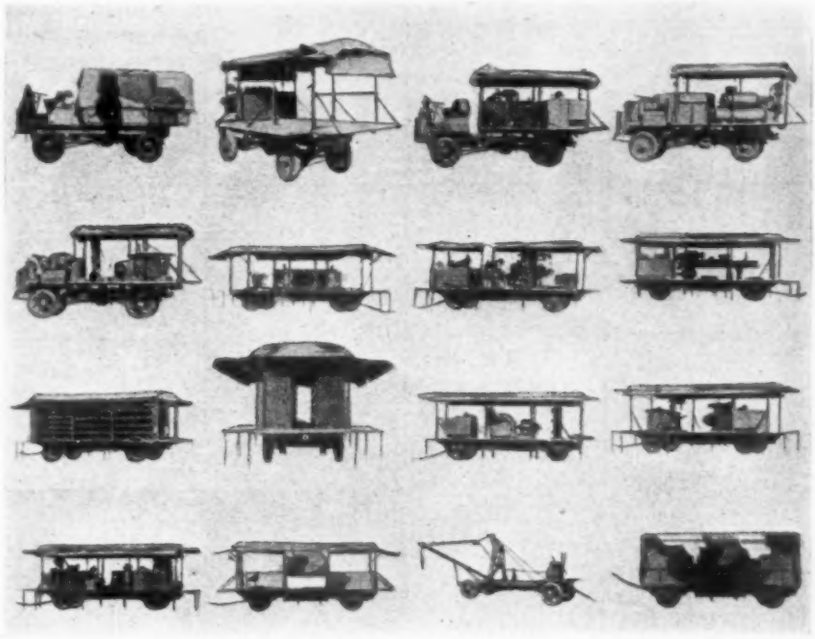
riers, the average infantryman goes into action carrying approximately 75 pounds. At least 40 pounds of this could be carried for him on the line of march, and 20 pounds while in action, by a few cross-country transport wagons of suitable capacity attached to his regiment.

Any means for reducing the load carried by infantrymen, whether on the line of march or in battle, is today one of the most important questions to be solved. The tremendous loss of equipment, due to soldiers abandoning the same just previous to going into action, is almost inconceivable, and by having part of the infantryman's load carried for him, immense loss would be saved.

Now take the infantry carrier itself. The transport wagon could be so designed as to carry many men fully protected from machine-gun bullets. After the enemy's fire had been smothered by fighting tanks, or a position taken, the bringing up of the infantrymen, protected from fire on the way, to consolidate and hold the position, would be a tremendous advantage, and the men so brought up, free from fatigue, would be worth double their number in men who had had to make their way forward under fire.

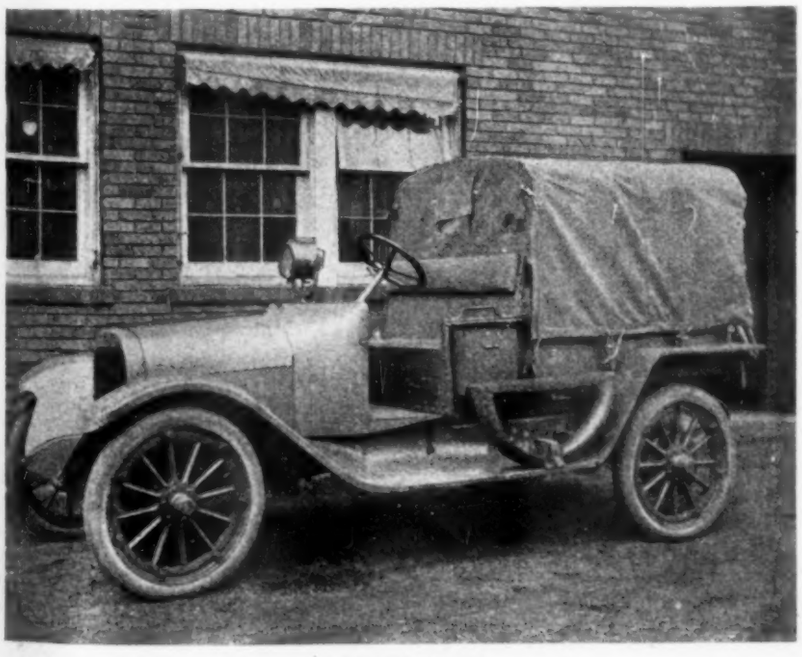
The future cross-country ambulance will be so supported that ordinary irregularities of from ten to twelve inches of the ground will not change the level of the body floor, it will be free from jolting, and will permit of operations being performed while traveling to the rear. A sufficient number of ambulance stations of this character, protected from bullets, would make the field hospital in many cases unnecessary, thus saving both in stretcher bearers and equipments.

Our present staff and reconnaissance automobiles are capable only of road travel. Soon, cross-country vehicles will take their place. With the armies of the future, tanks, capable of going from 15 to 20 miles an hour, will function as advance cavalry, with less loss and more effectiveness.



Repair Shop Vehicles of Heavy Ordnance Maintenance Company

In a recent manœuvre, I understand, a cavalry charge was made point blank on a battery of 18-pounders protected by two machine-gun nests so placed as to give a perfect enfilading fire protection to the battery. After the manœuvre was over, the officer in charge of the cavalry reported the position as won. This would have been perfectly feasible had the attacking force been cross-country cars; but it is inconceivable that the cavalry could force a sufficient number of horses up to capture a position so protected by machine-gun fire. The cavalry claim that their horses can get forage from the country through which they pass, while tanks can not secure gas in the same way. But one of the first measures of protection in modern warfare is to destroy all possible means of supporting either men or animals. Col. J. F. C. Fuller, D. S. O., in a report to the British War Office presented the interesting figures given in the table on page 314.



Light Repair Truck

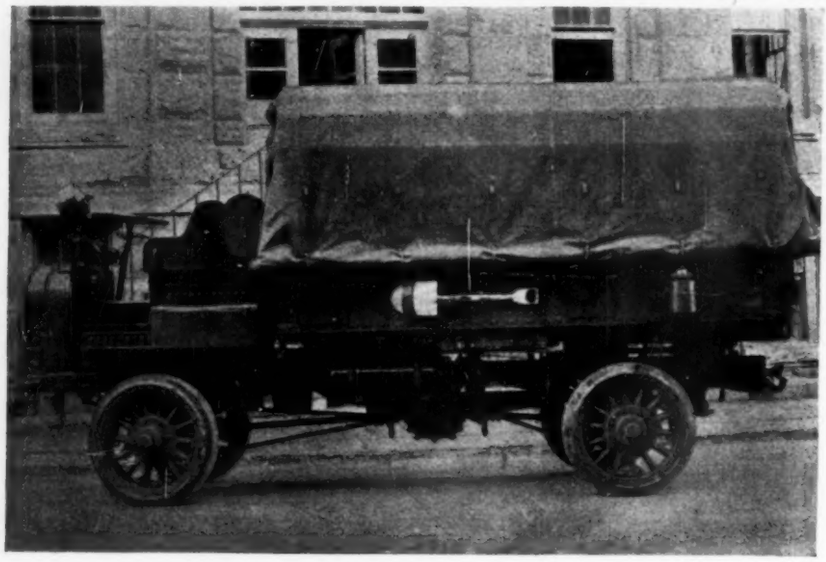
"1. On the following calculation, the 3 cavalry divisions now in France in food and forage (without reckoning wastage) require for one year 73,080 more tons of food and forage than an equivalent number of tank brigades do for one year's supply of food and petrol, etc. The saving

in tonnage, therefore, is approximately 90 per cent.

Cavalry Division	*Men*
Total personnel, less R. H. A.	7,406
	Tons
Food for men per month	200
Food for horses per month	2,100
Total	2,300

Saving, 2,030 tons per month.

Light Tank Brigade	*Men*
Total personnel	2,710
	Tons
Food for men per month	70
Petrol for tanks for 100 miles per month	200
Total	270



Artillery Supply Truck

2. Since they have been in France, the horses of the cavalry divisions have eaten a weight of food which is equal to the meat ration of London and the Home Counties (10,000,000 people) for a period of more than two years.

3. The number of horses in the cavalry divisions is a small item when compared to the total number in France, which probably exceeds 400,000 horses and mules. The food required for this number approximates 80,000 tons per month, or 720,000 tons per year. If half these animals could be replaced by petrol-driven tractors, road and cross-country, over 250,000 tons of shipping would be saved yearly.

Economy of Petrol Over Hay

1. For purposes of comparison, the case of a field artillery brigade, which at present entirely relies on horse flesh for movement is taken.

2. The brigade, exclusive of the brigade ammunition column, has 723 horses and mules, of which about 560 are used entirely for transport work and its supervision. These 560 animals require 4 tons of food per day, or 1,460 tons per year.

3. The haulage of guns and ammunition could be done quite as efficiently by cross-country tractors, 6 per battery, 3 for ammunition and 3 for the guns.

4. Four tons of petrol should take a light cross-country tractor a distance of 1,000 miles. If 24 tractors are used, each could average 40 miles a day, or 14,600 miles a year, on the same tonnage of petrol as the 560 horses at present require in tonnage of hay and oats."

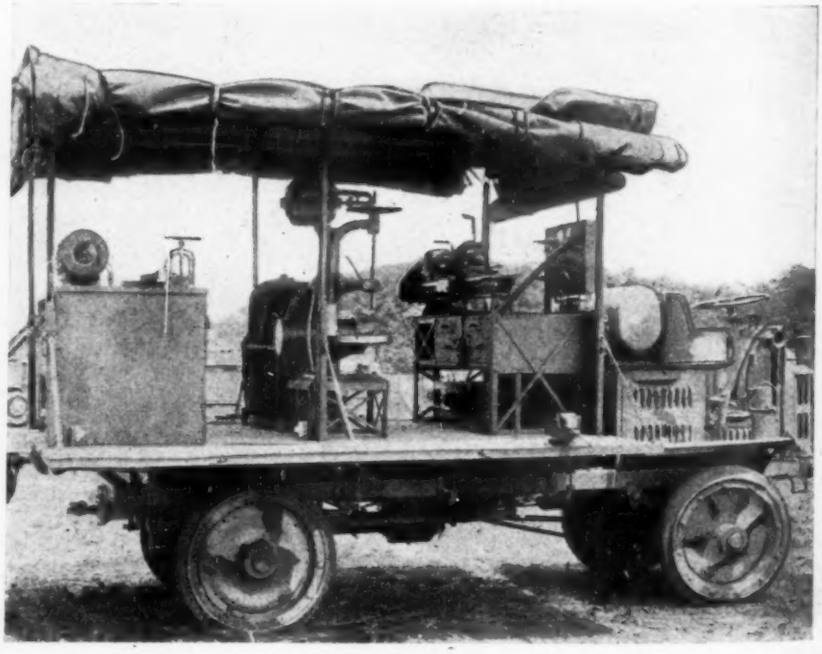
In civil life it is already being seen that the horse is being supplemented by automobiles and farm tractors. Only in a few isolated cases has the horse been found economical, and the raising of horses, except as a luxury, will soon become a lost art, land now used to raise food for horses will be turned to supporting man.

What will be the standardized line of development of the cross-country vehicle of the future? It seems safe to predict that the development will be along the following lines:

First. The present type of direct-connected track shoes will be superseded by centipede self-adjusting shoes, the soles of which will be of rubber or wood inserts.

Second. The articulation of the frame with a rigid bogie will be superseded by a machine in which the frame is rigid and the bogie is articulated, for with the rigid bogie any slight raise requires an engine pull equivalent, not only to the power required to travel on the track, but to lift the machine over the irregularity, while in the second, the articulation of the bogie permits the track to go over the irregularity without appreciably raising the machine.

Third. An automobile fitted with a centipede track which can be lowered or raised at the will of the driver to permit of either method of locomotion may be an intermediate step pending the development of the cross-country vehicle to the same stage as that of the present automobile. The commercial caterpillar at present is not an economical machine, for on farm work the total average use per year is only 38 days. Practically no improvement has been made toward making



Artillery Repair Truck

track pins dust-proof, or built-up shoes with wearing parts replaceable at slight cost. Nevertheless there is no reason why a machine can not be built at a reasonable cost which the farmer can use for either cultivating or transporting his products to the market.

Mobility is a prerequisite to the success of an army. Cross-country vehicles assure mobility with a minimum of cost and the employment of a minimum number of men and animals. But it is both militarily unwise and economically unsound to leave the development of an instrument of transport which may be used in war, but which has also valuable commercial qualities, to the day when such a vehicle is required for war purposes. As in the case with the aeroplane, this development should begin in time of peace; the people at large should profit by it in their daily pursuits. Then when war comes, if it should come again, not only would a more highly perfected instrument of transport be available, but factories all over the country would know how to make and be in a position to turn out as many as the army might require.

To this end, obviously, since the government is interested from a military standpoint, and since also the people at large are interested from the standpoint of increasing means of transport, reducing freight costs and the costs of farm production, it is legitimate to expect that a charge for experiments in cross-country vehicles would be a normal one against the Federal purse.

Certainly, in saving in road upkeep costs, increased and cheaper transport and lessened cost of farm production and marketing, such an appropriation would be one of the most paying investments the national government could make.

Tanks With Modern Improvements

By

RAYMOND E. CARLSON
Member A. O. A.

THE tank has been described as a deaf, dumb, and blind beast, which is no doubt a true description. This article will cover briefly a few of the items, or "gadgets" as our English cousins call them, which are necessary to give tanks eyes, ears, and some of the other attributes which the human being possesses, so that the tank, through the crew, will become an efficient fighting machine. The following subjects will be briefly touched upon:

A. Observation,
B. Direction,
C. Communication,
D. Gas Protection,
E. Cooling.

A. *Observation.*

The tank is somewhat like an individual afflicted with a bad case of shortsightedness, or one who has been to the eye doctor to have eye drops in his eyes and has to wear dark glasses. The observer is closed in by steel walls, which are bumping around violently when the tank negotiates rough terrain. Observation is obtained through slits, which of necessity must be very small, and the observer has great difficulty in keeping his eye properly located with reference to the slit and at the same time prevent injury to himself through bumping against the steel side of the tank. A small periscope is also used when enemy fire is severe. This periscope is pushed up through a hole in the top of the tank, and being small in size is not often hit. Observation from a periscope, however, is limited to observation in the direction the periscope is pointed.

Since tanks were first used, much time and effort have been spent with a view to securing better observation and at the same time providing protection to the observer. So far the scheme which gives most promise is an application of the stroboscope principle. The stroboscope as applied to tanks consists of an outer cylinder which revolves at 300 or 400 revolutions per minute. In the sides of the cylinder are placed vertical slits having a width of approximately 2 millimeters. The width of these slits is dependent upon the size of the core of armor-piercing bullets, and they are made sufficiently narrow so that even though a bullet should hit directly on the slit, the steel core would be prevented from going through. Inside of this outer cylinder, which is revolved by means of an electric motor, is another cylinder, which remains stationary and is fixed to the tank. This cylinder has windows of non-shatterable glass so arranged that in case any molten lead or splash comes through the outer slits and splinters or blurs up the window, this window can be easily and quickly replaced by a clean one.

Most every one has noticed while walking alongside a picket fence that the pickets seem to have very little effect on the objects behind the fence, or that while looking through the spokes of a wheel which is turning the spokes only slightly dim the clearness of an object behind the wheel. The stroboscope operates on exactly this same principle. The retina of the eye will hold an image for approximately 1/10 of a second, and if sufficient slits are put in this outer revolving cylinder and the cylinder turned at a speed so that a new slit will be presented before the line of vision of the eye within the time period of 1/10 of a second, practically continuous observation will be obtained.

Sample stroboscopes, substantially of the type shown in the illustration, have been made and tested out under fire, and the results of these tests have been very satisfactory. The slits are so arranged that the observer, whose head is inside of the inner cylinder, can move about considerably and still have good observation. During the tests a dummy observer was placed inside the cylinder and machine-gun and rifle fire directed on the outer screen, and the conclusions reached as the result of these tests were that the observer would not have been injured.

The stroboscope seems to possess the greatest possibilities for giving the tank driver or commander all-round observation, and at the same time affording him the maximum degree of protection.

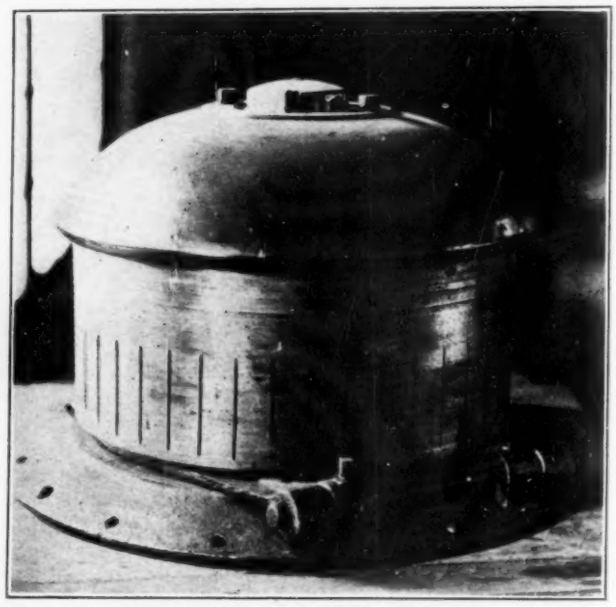
B. *Direction.*

In order that tanks may follow prescribed routes which

have been assigned for the fulfillment of a certain mission, and in order that they may have accurate information available as to their location at all times, it is necessary to provide them with suitable radio directive apparatus or reliable compasses. This article will deal only with the investigations and work now going on in connection with compasses.

During the past war magnetic compasses of the airplane type were provided for tanks and were used with fair success. The tank is not well suited for the use of an ordinary magnetic compass on account of the fact that its hull forms a magnetic shield and that the revolving track shoes and firing of steel projectiles upset the magnetic distribution. Experiments are now being made by the Bureau of Standards for the Ordnance Department, as the result of which it is hoped that satisfactory forms of shielding and compensation can be developed, which will give the magnetic form of compass sufficient reliability to permit its use in tanks.

In order to provide a compass which is absolutely independent of the earth's magnetism, there is being developed by the Sperry Gyroscope Company, for the Ordnance Department, a gyroscopic compass which, it is believed, will be of great value to the tank. As is well known, the gyroscopic compass obtains its directive force through the inter-reaction of the earth's rotation and the rotation of the gyro wheel, the latter at the equator always tending to keep its axis of rotation parallel to the earth's axis. The gyroscopic compass being developed for tanks is of the direct-current type, and the energy necessary for revolving the wheel is obtained from the starting and lighting batteries of the tank. This compass is independent of any magnetic influence, and should, when perfected, provide a very reliable means of enabling the tank commander to follow any course desired. An added advantage of a gyroscopic compass is that it indicates true north and not a magnetic north, so that deviation corrections are not required.



Experimental Stroboscope for Tank Observers

This gyro compass has really great possibilities in broadening the field of employment of tanks. It can easily be provided with a means whereby it would trace on a chart the course which the tank has followed up to any one point, and in case it were desired to retrace this course, the tank would then be steered so that the recording device would follow the course already marked up. During the past war, submarines equipped with gyroscopic compasses and this recording device went safely through the Mediterranean and up to Constantinople. When the return voyage was attempted, the submarine was steered according to the chart already made and returned safely to its point without encountering mines. The use of gyro compasses on tanks would enable night attacks to be made or allow them to go forward during early morning raids or even in the fog.

C. *Communication.*

A tank without ears, so that it does not know what is going on around it, or without speech, so that it can not tell other tanks or other troops what is happening in its immediate vicinity, is not the most effective tank. First of all, the various members of the tank crew must be able to talk easily and clearly with one another. Next, the tank commander must be able to talk to other tanks, to Tank Headquarters in the rear, or to airplanes. The development of wireless telegraph or telephone communication from the tank to other outside parties is a function of the Signal Corps, and will not be covered in this article. It is pertinent to remark, however, that good progress is being made on this problem.

The question of communication between members of the crew has been satisfactorily solved through the use of a throat-type transmitter. In the Mark VIII the tank commander can talk to the driver, the right or left-hand gunner and mechanic, and all of these outlying stations can in turn talk to the commander, so that the tank commander is, in effect, a real commander, and can give definite orders to any member of his crew with the knowledge that these orders will be clearly understood. In order to thoroughly appreciate what this means one has only to ride in one of these heavy tanks when they are in motion. The Mark VIII tank is perhaps better than most of the other large tanks, because the fighting compartment is separated from the engine compartment, but even so there is still a great amount of noise. A head set consisting of two special receivers and a throat-type transmitter are provided for the tank commander, the driver, mechanic, and both gunners. This head set is so arranged that the gas mask can be easily worn as well as the leather skull cap which each member of the tank crew needs to provide protection for his head. In addition, an extra head set and a 30-foot extension cord are provided, so that when the tank is moving in the dark during an approach march a man walking out in front can give orders to the driver. This intercommunicating telephone system, which is in effect a very small telephone exchange, draws its power from the starting and lighting batteries on the tank.

D. *Gas Protection.*

The scientists tell us that gas is now being developed which is far more powerful than any other gas previously used, and in the same breath they say that gas masks are being provided to render the wearer immune from this gas. There is little doubt but what gas will have a most important role in the next war, and the side which has an effective gas for which gas protectors have not been invented by the other side will have an enormous advantage. It is believed that tanks can play a very important part in minimizing possible disaster which might occur through the use of gas. Tanks can be made gas-tight, and if the members of the crew are then provided with oxygen, or air, they have little to fear, no matter what kind of gas is used. With a relatively small number of these gas-proof tanks, centers

of resistance could be set up which would prevent an absolute disaster to the forces.

Studies are now under way in collaboration with the Chemical Warfare Service for a means to make tanks proof against toxic gases, the importance of which is thoroughly recognized by the Ordnance Department.

E. *Cooling.*

Tanks are called upon to operate in almost every extreme of climate, from very cold to very hot weather, and the question of cooling them, to insure satisfactory operation, is a very important problem. So far the cooling system for tanks has been of the more or less standard type, employing radiator and cooling fan, which was driven either by belt or by chain. This system is, of course, open to the criticism that water used as a heat absorbing medium may freeze in winter or under extreme cold, and it may not possess adequate cooling for use in tropical climates.

The possibility of using a small refrigerating plant for cooling the engines where tanks are required to operate in tropical countries is now receiving considerable attention and may give a solution to this problem. So far, details of this investigation are not available, but it is thought that the refrigeration system will be first applied to extracting the heat from the cooling water and thereby replacing the radiator and fan at present used.

The cooling of the entire tank, or at least the portion in which the crew is confined, is also an important problem. The tank necessarily being of metal construction, becomes a veritable oven when exposed to the sun's rays, so that unless artificial means of cooling are provided, the crew performs its work only with the utmost difficulty.

The Experimental Determination of the Forces on a Projectile

By

G. F. HULL
Member A. O. A.

THERE are two elements of importance in an artillery duel. If one of the adversaries out-ranges the other, and also possesses the greater accuracy, to him will belong the victory. That is especially true in naval battles. The two battles in South American waters during the World War were both decided by these two items.

Projectiles are robbed of their range by the resistance of the air. Their flight is rendered uncertain by the same cause. If we could get rid of the resistance of the air, the army service bullet, .30 caliber, would have a range of 43 miles. Moreover, it would have an energy and a penetrating or destructive power at the end of that range equal to the corresponding values at the beginning. All projectiles would have the same range—given the same muzzle velocity and angle of elevation. Accuracy in range would not depend on the size or shape of the projectile.

For years all countries tried to improve the range of their projectiles. Early in the war it appeared that the Germans led the way. Then the Allies hastily tried to overtake them. There was great progress during those few years, but the race is far from being finished.

Let us consider these two elements—range and accuracy. How may we improve them? The ordinary way has been to fire projectiles with known powder charges and note the range and dispersion; then to modify the projectiles and start all over again. But that is a cumbrous and expensive method, and has led to very indifferent results, although it has been used for a century. If we could determine completely the laws governing the resistance of the air, then we could calculate the range of any projectile. And if we knew all the factors entering into the resistance, we could design a projectile which would possess a maximum of range and a minimum of dispersion.

The classical method of finding the retardation of a projectile has been to fire through a number of screens and note the rate of decrease of velocity. This may appear easy, but in practice it is a matter of considerable difficulty. For, in order to measure retardation to one per cent, the velocities would have to be measured to an accuracy of one part in ten thousand. An experiment along this line, which promises far more precision than any previously undertaken for this purpose, has been started at Aberdeen Proving Ground to supplement the experiments described in this article.

In the fall of 1918, experiments were begun by the Ordnance Department and Bureau of Standards which had for their object the measurement of the forces on a projectile due to its motion through the air. Here it was proposed to hold the projectile in an air stream of high velocity. The General Electric Company was able to supply at its Lynn plant a stream of air about one foot in diameter up to velocities perhaps as high as 1,500 feet per second. It may be pointed out that a wind of 90 feet per second, or 60 miles per hour, is regarded as a gale. Now, power goes up as the cube of the velocity. Hence it requires 1,000 times as much power to produce a stream of 600 miles per hour as to produce one of 60. For a velocity of 1,500 feet per second the power required would be 4,600 times as great. If we assume that 30 per cent takes the form of thermal energy and only 70 per cent takes the form of the kinetic energy that we desire, it can be easily computed that the power required to produce a 1-foot diameter wind stream of a velocity of 1,200 feet per second is 8,600 H. P., or 6,300 kilowatts. If this had to be paid for at an electric-light rate of 10 cents per kilowatt hour, the cost would be more than *ten dollars a minute.* However, through the courtesy of the General Electric Company, we have been able to utilize commercial tests of compressors, and the Government has been called upon to pay for only a small part of the power it has used.

The apparatus now used for measuring the forces on the projectile is illustrated in Fig. 1. The projectile is attached

by a steel spindle to a steel piston working in a cylinder, the latter being attached to a horizontal bronze bar which can be moved in and out, or up and down, in the wind stream. The pressure of the air above the piston can be regulated and measured. Hence, when the upward force of the air on the projectile is equal to the weight of the moving system, the piston moves up or down in the cylinder, or a "balance" is obtained. As far as this "weighing" is concerned, the accuracy depends upon the precision of fit of piston and cylinder. This precision is such that, although only lubricating oil is used between the surfaces, air does not leak in or out to any appreciable extent. At the same time a difference of force of 0.04 pound will cause the piston to change from an up to a down motion, or vice versa.*

The velocity of the air and its temperature, after it has issued from the orifice, are computed by the use of the ordinary formula holding for adiabatic expansion. It is necessary to measure the pressure and temperature of the air in the pipe below the orifice, that is, before expansion. For this purpose a number of pressure gages and thermo elements are used. A potentiometer, a galvanometer (suspended so as to be undisturbed by the very pronounced vibrations of the building) and an air pump capable of producing suction or pressure, are also necessary. Photographs of the air waves about the projectile, especially at high velocity, give an indication of the disturbing causes and also provide a check upon the computed air velocity.

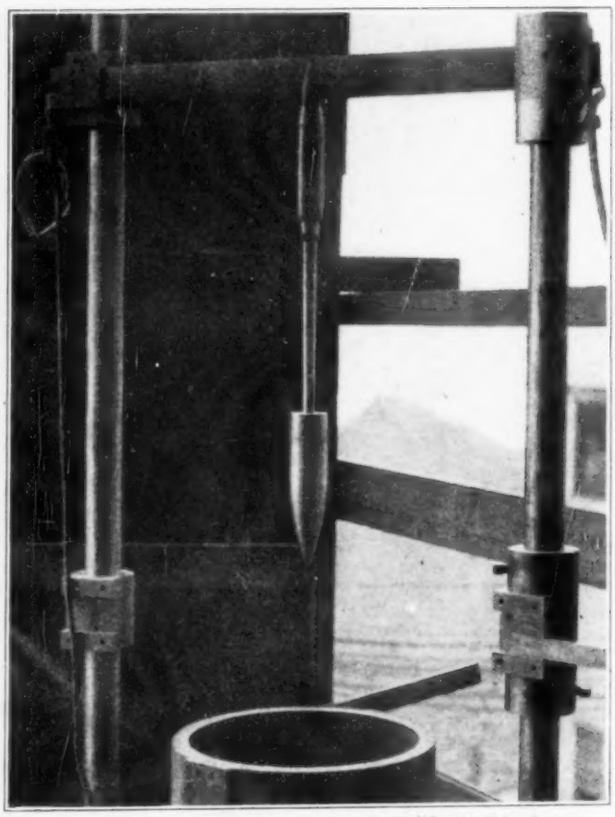


Fig. 1. Apparatus for measuring forces on a projectile "floating" in air stream—velocity 1,200 feet per second

There are a great many variables in this experiment and there are a great many corrections to be applied and standardizations to be made. But, finally, we can say that we know the force which an air stream of a certain velocity, density, and temperature will exert on a projectile of a certain specified form. For a number of definite forms we know the law of air resistance between the ranges of velocity so far used, that is, from 200 to 380 meters per second (about 600 to 1,200 feet per second). And we know the effect upon the resistance of adding a rotating band to the projectile fore or aft.

But it may be argued that we must have known the law of air resistance for years, otherwise how could we have constructed range tables. It is true that we follow the French law in this work, but it will be seen in Figs. 2, 3, 4 and 5 that that law does not hold even approximately for modern projectiles, within the limits of the velocity we have used. The French write the law in the form—

$$R = c\rho d^2 V^2 B(V).$$

†Hence, R/V^2 varies as $B(V)$ where $B(V)$ is a function of V, which, when plotted, has the form of the dotted line in Figs. 2, 3, 4, and 5, and the full line in Fig. 6. Now, projectiles illustrated in Figs. 2, 3, 4 and 5 may be regarded as modern, and for these the resistance law departs widely from the B curve—the curve which is the basis of all our ballistic computations. These curves also show that for low velocities (V=200 to 250 meters per second) the force due to the air does not depend very much upon the form of the nose, but that it does depend very critically upon the form of the base. Thus, boat-tailing a projectile 9° cuts the force in half for $V=200 m/s$. At low velocities the 9° boat-tailing is rather better than a 7° or a 5°, but this advantage soon disappears as the velocity increases. Our curves suggest, though they do not in any way prove, that at high velocities the retardation of a boat-tailed projectile is not much less than that for a square base.

It is clear then that when we speak of the "best form" projectile, we must specify the velocity for which this form applies.

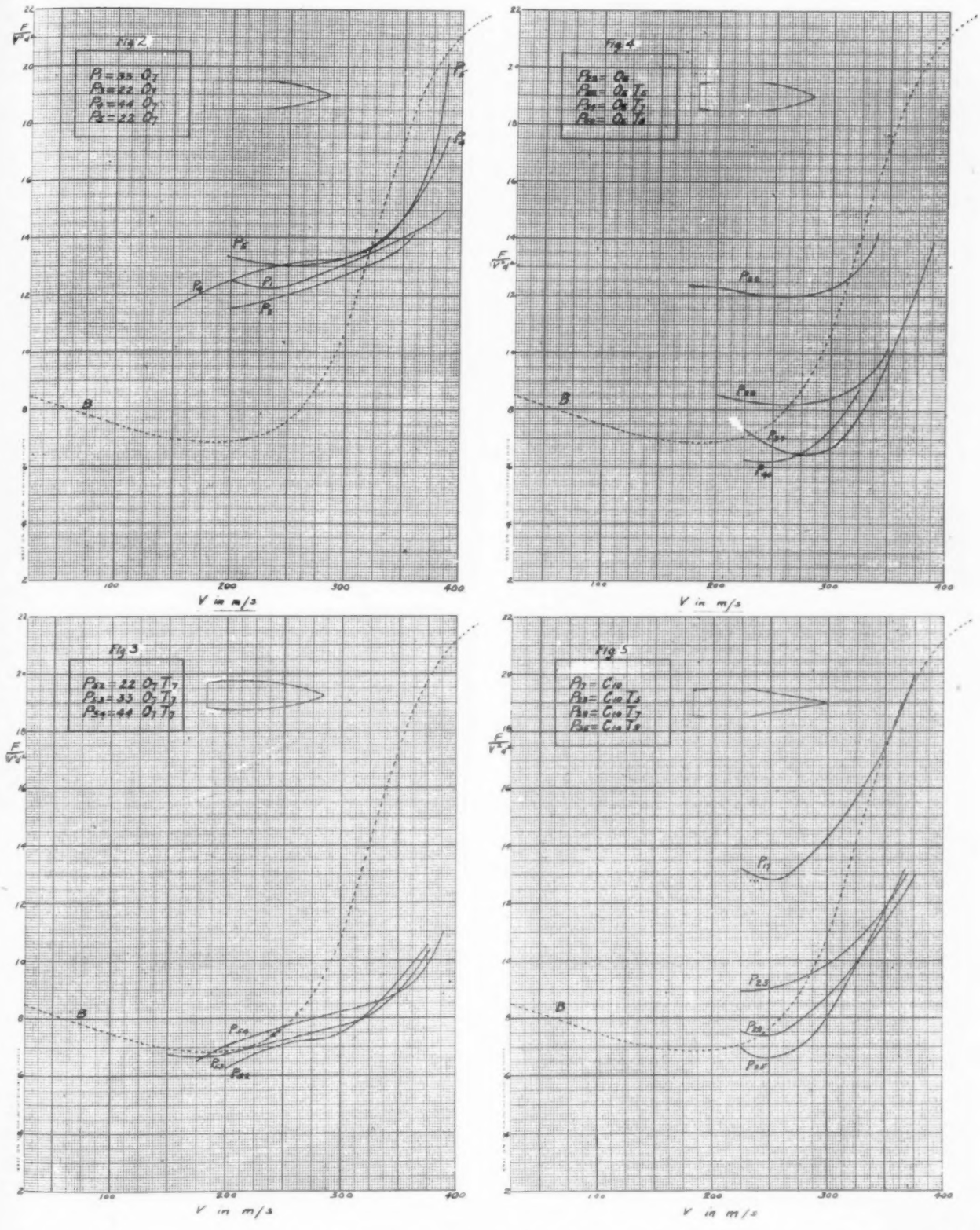
The important part played by the base of the projectile is further made evident by the measurement of the pressure of the air across the base. For a square-base projectile, the pressure is fairly constant at all points across the base. This pressure is negative when compared with atmospheric pressure, and therefore is suction. The data of Table I shows that at low velocities the force due to the base is four-fifths of the total force for a 7-caliber ogive projectile. If the area of the base is decreased by boat-tailing, and if, as our measurements show, the suction also decreases, then the force due to the base is greatly decreased and the total force on the projectile is similarly affected. Table I shows the suction in centimeters of mercury at the base of a projectile. To interpret this suction in pounds per square inch, one has to divide the number of centimeters of mercury by 5.17.

The data shown in Figs. 2, 3, 4 and 5 were obtained without any rotating band on the projectile.‡ The addition of a rotating band may greatly increase the force or may have no effect, depending upon its position. For a square-base projectile, a band flush with the base increases the force by

*Under the direction of Dr. L. J. Briggs, of the Bureau of Standards, who is collaborating in these experiments, these cylinders and pistons were made by Mr. W. H. Cottrell, to whom is due great credit for excellent workmanship.

†In this equation
R is the resistance of the air,
V, the velocity of the projectile,
d, the diameter of the projectile,
c, a constant,
ρ, the density of the air.

‡In these figures P_1, P_2, etc., refer to the numbers of the projectiles; the first digit to the right of the equality sign is the diameter of the projectile in inches, and the second digit is the length of the cylindrical body in units of 1.86 inches; the letters O_5, O_7, etc., refer to the radius of the ogive in calibers, while T_5, T_7, etc., refer to the amount of boat-tailing in degrees.



from 10 to 15 per cent. But if the band is placed slightly away from the base there is no appreciable increase over the case of no band. For a boat-tailed base, placing the band at the beginning of the base cone increases the force from 20 to 50 per cent. In the case of a long coned ogive, a band placed at the end of the ogive may produce an increase in force of over 50 per cent, while two bands at the end of the base and nose cones may produce an increase of 100 per cent. Clearly, then, small irregularities in the form of a projectile may bring about a surprisingly large increase in the retardation. Table II shows some of the variations of force due to the positions of the rotating band.

The forces plotted in the curves here shown were measured when the projectile was held nose-on to the air. There

have been indications that when the projectile was inclined to the air stream, the force was greatly increased. For example, in one cast, when a projectile weighing nearly fifty pounds was in the air stream, the nose-on force was a little over 40 pounds. There was then a down force on the spindle. But as the projectile was being taken out of the air stream it was set swinging slightly. The air caught it on one of its swings and threw it up several feet, breaking off in that motion the steel spindle holding the projectile to the balance arm. It was evident that the inclined force must have been at least twice as great as the weight of the projectile.

By attaching the projectiles to the spindle at an angle to

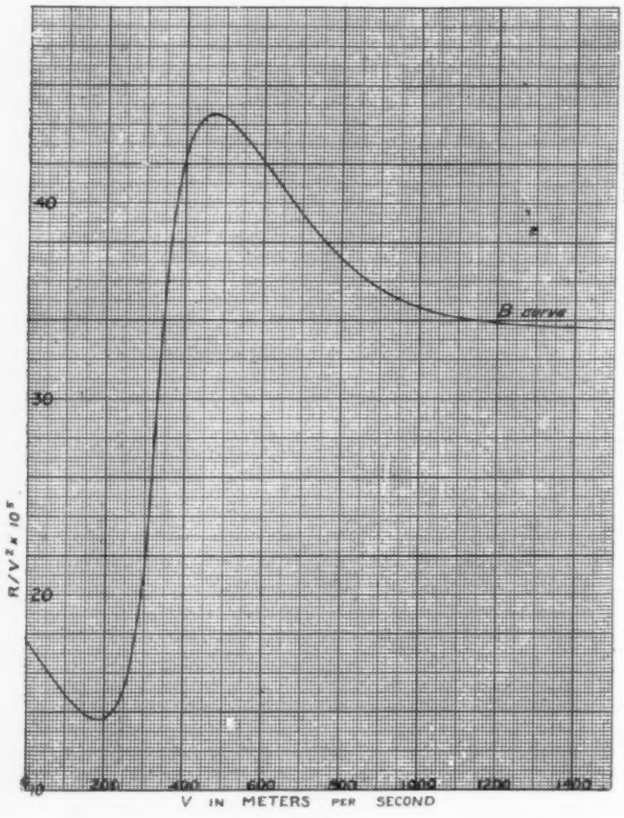


Fig. 6

the axis, the force in the original direction of the air stream may be found for an inclined position. The data in Table III have been obtained recently and may require revision. These measurements show that the retardation of a projectile may be increased two and one-half times by a change in direction of the axis of the projectile through 15 degrees. Now, ballisticians have never taken any account whatever of the change in inclination of the axis of the projectile to the wind. They have regarded it very much as if it were a sphere—namely, as if the force on the projectile was independent of its orientation. But our data show how serious an error may be made in following that assumption. At high altitudes the wind velocity may be very large and may easily cause a 15-degree attack of air upon a projectile. In such a case, if the projectile is a stable one, its rapid rotation will cause the nose to precess about the apparent direction of motion of the air, and it may, in time, meet the air nearly nose-on, but it may continue to have a large yaw, in which case its retardation will be several times as great as it would have been had it moved nose-on to the air.

Experiments concerning the stability of a projectile are being very ably conducted at Aberdeen by Mr. R. H. Kent. His problem, involving as it does the consideration of precession and mutation of a spinning body advancing through the air at great speed, is one requiring not only mathematical ability of a high order, but one demanding the closest scrutiny of experimental results.

The problem of the projectile has never been regarded as an easy one. Even in the older pre-war days of small angles of elevation and short ranges, it was known that there were a number of variables which influenced the projectile's flight. But now it is necessary to explore the upper, as well as the lower, air for temperature and wind before a shot can be accurately directed. And it is necessary to know many facts concerning the projectile which formerly were never taken into account. With all of these facts, and with range tables based upon a correct law of resistance, we may determine not only the range of a projectile, but we may accurately follow it through its whole course of flight. It is in order to supply as many of these facts as possible that these experiments are being conducted.

TABLE I. *Data showing pressures of the air at the base of a projectile.*
Projectile No. 3, square base, 7-caliber ogive.

V m/s	Suction at base in cms. of Hg.	Fo= Force due to suction at base	F= Total force	Radio Fo/F
198	2.3	1.53	1.99	.77
230	3.2	2.19	2.52	.80
285	5.3	3.51	4.00	.87
298	5.3	3.40	4.40	.80
322	5.5	3.65	5.40	.70

TABLE II. *Variation in force due to change in position of rotating band.*
Distances of the band measured from the base.

Projectile No. 3, square base, 7-caliber ogive.

V=215 m/s			V=235 m/s			V=280 m/s		
Position of band	Force/V²	Ratio	Position of band	Force/V²	Ratio	Position of band	Force/V²	Ratio
no band	530	1.00	no band	520	1.00	no band	535	1.00
0	580	1.00	0	590	11.13	0	625	1.16
.2 inch	520	0.98	.2 inch	534	1.03	.2 inch	570	1.07
.3 inch	530	1.00	.4 inch	520	1.00	.4 inch	540	1.01
.5 inch	540	1.02	.6 inch	535	1.03	1.0 inch	5.60	1.05

Projectile No. 52, 2-inch diameter, 7-caliber ogive, 7° boat-tailed.

V=250 m/s			V=280 m/s		
Position of band	Force/V²	Ratio	Position of band	Force/V²	Ratio
no band	29	1.00	no band	30	1.00
1.00 inch	37	1.26	1.00 inch	40	1.33
1.25 inch	35	1.20	1.5 inch	37	1.23
			2.0 inch	38	1.26

Projectile with coned ogive (20° total vertical angle).

V=280 m/s			V=280 m/s			V=280 m/s		
Projectile No. 23, 5° boat-tail			Projectile No. 29 7° boat-tail			Projectile No. 35 9° boat-tail		
Position of band	Force/V²	Ratio	Position of band	Force/V²	Ratio	Position of band	Force/V²	Ratio
no band	394	1.00	no band	326	1.00	no band	283	1.00
1.0 inch	432	1.10	1.0 inch	413	1.27	1.0 inch	434	1.53
1.5 inch	418	1.06	1.5 inch	370	1.13	1.5 inch	320	1.13
2.0 inch	418	1.06	2.0 inch	378	1.16	2.0 inch	320	1.13
at ogive	516	1.31	at ogive	562	1.72	at ogive	450	1.59
Band at each cone							580	2.05
Two bands midway between cones							332	1.17

TABLE III. *Variation of force due to inclination of projectile.*

Projectile No. 53, V=200 m/s					Projectile No. 1, V=200 m/s				
0°	2.5°	5°	10°	15°	0°	2.5°	5°	10°	15°
255	287	345	475	660	410	500	530	715	880
Projectile No. 53, V=270 m/s					Projectile No. 1 V=270 m/s				
0°	2.5°	5°	10°	15°	0°	2.5°	5°	10°	15°
5.2	5.5	6.3	8.1	---	8.4	9.8	10.2	14.9	---

Preservation of Dies, Patterns, Tools, Jigs and Fixtures

By

W. E. SIDNEY

Member A. O. A.

AFTER the signing of the Armistice the matter of preserving and storing the dies, patterns, tools, jigs and fixtures which had been used in producing Ordnance Motor Equipment, was realized as of importance to enable reaching prompt production in case it should be necessary to obtain large numbers of motorized artillery vehicles and tanks in an emergency, and also for the peace-time manufacture of spare and reserve parts.

About 80,000 such dies, patterns, tools, jigs and fixtures were scattered over a large area at different manufacturing plants where they had been used in connection with war-time contracts. There was also much valuable manufacturing data in the form of Route Sheets, etc., which it was necessary to preserve, as well as personnel and funds would permit. After serious consideration a decision was reached to store all this material at some central point, and on account of its location Rock Island Arsenal was designated as the permanent storage depot for all dies, patterns, tools, jigs and fixtures, with the exception of those used in connection with armor plate, for all material under the jurisdiction of the Tank, Tractor and Trailer Division. The central location of Rock Island Arsenal enables prompt distribution to contractors in case of necessity, and also enables their use at that point for the manufacture of repair and reserve parts, which work will be carried on by the Arsenal for supplying peace-time needs.

The rounding up of this material required a vast amount of work, and, as it was soon seen that satisfactory results would not be accomplished in the usual routine of war-settlement work, the Chief of the Tank, Tractor and Trailer Division assigned an officer to the work whose duties consisted solely of locating, attending to the shipping and storing of this material at the designated central storage point, and of preparing records and instructions that would insure the material being really useful when required.

Careful study was given to the forms to be used in recording the data necessary for a complete record of this material, and those were finally adopted which are illustrated herewith. The workings of the system adopted are fully described by the following quotations from the instructions which were issued not only for use in compiling these records, but with the view of being so clear that they could be understood by a prospective manufacturer entirely unfamiliar with the normal operations of the Ordnance Department. All terms used as captions on the record form (Fig. 1) are defined, and an explanation given as to the information to be shown under same.

Equally careful instructions were issued regarding standard reamers, taps, dies, drills, etc., but as these items will probably be gradually used up in time of peace, and as there is nothing particularly novel in the methods used, the instructions and forms used are not included in this article.

(a) *Manufacturing Equipment Record.* This term as used herein will mean a record of all patterns, dies, tools (other than machine tools), templets, jigs, fixtures, and such gauges as are clearly a working part of such, but does not include gauges used for inspection purposes. The record will, under the various headings thereon, consolidate information essential to proper identification and location of equipment from the various sources available at Rock Island Arsenal, viz, shipping tickets, R. I. A. Central Tool Storage Checkers' Report (Form SF265), R. I. A. Abstracts of Manufacturing Equipment (Form SF334), Ordnance Department Drawings, O. O. Forms 5817, List of Tool, Jig and Fixture (Forms TF66), Contractor's Tool Drawings, Contractor's Route Sheets, Index Cards, and other miscellaneous sources. However, this record will be particularly allied to Central Tool Storage Record Card (Form SF104), which constitutes the principal record of this equipment maintained at Rock Island Arsenal.

(b) *Sheet -- of -- Sheets.* This term is used for the purpose of keeping closely related record sheets in their proper place, and for indicating the total number of sheets pertaining to a given component, as there will be numerous instances where it will require several sheets to properly list all the equipment used in the manufacture of a given component or part. In all cases the number "1" will be written after the word "sheet" on the first sheet used, and each additional sheet required will be numbered consecutively, as No. 2, No. 3, etc., and after the word "of" will be written the total number of sheets pertaining to the particular equipment, thus, if four sheets were required, this would be filled in for each sheet as follows:

Sheet 1 of 4 sheets.
Sheet 2 of 4 sheets,
Sheet 3 of 4 sheets,
Sheet 4 of 4 sheets.

(c) *Project.* This term as used herein will be understood to refer to a particular kind of vehicle, such as Artillery Tractor, Five-Ton Model, 1917; Mark VIII Tank, Ten-Ton Trailer, Model 1918, or other vehicle, and will in all cases be shown on all records except that in cases where more than one sheet is required, the *Project* need be shown on first sheets only.

(d) *Group or Assembly.* As used herein, the term refers to a number of component parts which assemble into some major unit of a vehicle, such as a transmission, motor, or radiator, which is in itself a more or less complete article, but is in turn assembled into a complete vehicle. Shown on first sheets only.

(e) *Name of Part.* This will be interpreted to mean the name by which any part is described on ordnance drawings, and should be correctly quoted in all cases; it need be shown only on first sheets.

(f) *Ordnance Drawing Number.* This will be understood to consist of three parts: (f1) class to which drawings belong, (f2) division to which drawings belong, (f3) the actual number of a particular drawing (Ordnance Classification of Drawings), as, for example, Drawing 31-33-372, which would read, Class 31, Division 33, Drawing 372. The ordnance drawing number must be shown on all first sheets, but need not be shown on additional sheets. There will possibly be some cases where equipment has been turned in from the manufacture of a part, or parts, for which no ordnance drawing has been made; these will, of course, be considered as exceptions to these instructions.

(g) *Ordnance Component Symbol.* As used herein means *Piece Mark*, which term is used in connection with all ordnance handbooks and drawings, but as the term component symbol is used on forms at Rock Island Arsenal, it has been used in these instructions to avoid possible confusion. It is derived from the ordnance drawing number, to which is added any other symbol used upon the drawing to specifically designate a particular component, as, for example, on Drawing 31-33-372 details are shown of *two* component parts, one part being identified on the drawing by the symbol "A," and the other by the symbol "B." It

is customary to drop the class and division when writing the ordnance component symbol, only the drawing number and symbol thereon being used; thus, in this case we have ordnance component symbols written 372A, which identifies an oil-pump body, and 372B an oil-pump upper cover. For the purpose of this record, the term will be understood and written as above explained, but it should be remembered that in cases where it is necessary to give the ordnance component symbol, as in correspondence, etc., the *Project* should be mentioned, together with the class and division to which the drawings of the project belong. In these records, the ordnance component symbol will be shown on first and all additional sheets regardless of the number of sheets required.

(h) *Contractor's Component Symbol.* As used herein this term will be understood to mean any identification numbers, letters, or other marking used by the contractor to designate various components other than that officially assigned on the ordnance drawing of the parts. In most manufacturing establishments the engineering, production, and accounting records are closely associated, various systems being in use by different manufacturers, and, as during the late war, it became necessary in some instances to place orders for materials for which no ordnance drawings were at the time available, it resulted in many different component symbols being assigned by the manufacturers which have no connection with the ordnance component symbol subsequently assigned, and as route sheets, index cards, tool symbols, etc., are all based upon the general system in use by the various manufacturers, it has been found that the contractor's component symbol is in many instances the only practical means of linking together the data required.

The contractor's component symbol will, when it is known, be shown on all first sheets, and in cases where ordnance symbols have not subsequently been assigned, on all additional sheets; they will also, in instances of this kind, be used the same as ordnance symbols for filing purposes.

(i) *Contractor.* By this term is meant the manufacturer directly responsible to the Government for the performance of work or the production of material, and the name of the contractor as so defined will be given after the caption "*Contractor*" on the first sheet in all cases. Where it is known that the contractor had the actual work performed by a sub-contractor, the name of such sub-contractor should be shown following that of the contractor; for example, Chandler Motor Car Co. (Maxwell Motor Company, sub-contractor).

(j) *Tool Symbol.* By tool symbol is meant any marking, stamped or otherwise, made upon any manufacturing equipment for the purpose of identifying same. These will be found to differ widely, as no fixed system of tool symbolizing has been used. There are a number of instances where equipment have no symbols marked upon them, but have been identified and tagged, being carried on Rock Island Arsenal Form SF104 by description; in such cases the arsenal is instructed to assign a symbol to such items under any system it may have in use, provided that where several items are identical and used in the manufacture of the same component, the same symbol will be used. The symbols so assigned will be considered as the permanent tool symbol for such items, and will be so used for the purposes of this record, and proper notation should be made upon the R. I. A. Form SF104. The tool need not at this time be removed from storage for symboling, but will, whenever withdrawn for use within the arsenal, or for shipment, be properly marked in such manner as will remain permanent. The tool symbol will be shown for all items of equipment entered upon these records.

(k) *Tool Drawing Number.* This term will be understood to refer to numbers or other identification markings used on drawings, tracings, and prints, covering the design and construction of manufacturing equipment. In general, patterns for component parts of vehicle material were made from standard ordnance drawings, and these are not to be confused with tool drawings as defined above; however, in cases where, on account of peculiar construction of pattern, the contractors have made special drawings to facilitate the work, they will be classed as tool drawings for the purpose of these records. Tool drawing numbers will be shown for each item entered in all cases where such drawings are available.

(l) *Quantity.* As used herein quantity means the number of pieces or items. In noting the quantity of equipment of a given kind, all items of similar design, construction, and dimensions, and bearing the same tool symbol, will be counted, and their sum stated as the quantity. On this particular point, the actual working tool or item should be considered, and the fact that in the case of reamers some might have handles attached while others are identical in every respect, carry the same symbol and are used for the same purpose, but are without handles, should not be considered a sufficient reason for listing as a separate quantity. If, in the judgment of the person supervising the work, it should in some instances appear essential, notation of such fact may be made under "Remarks." The quantity of all items entered on these records will be shown.

(m) *Condition.* This term will be understood to indicate whether an item of manufacturing equipment is complete or incomplete, and in the case of equipment in a semi-finished state at the time production was stopped, will note same as semi-finished, giving approximate state of completion in percentage. In the notations made under this heading the fact that some minor piece which can be easily and quickly replaced at small cost may be missing should not be considered as sufficient reason for noting as incomplete, but in cases where some essential major part of such item is broken or missing, notation should be made under *Condition*, and further facts given under *Remarks*. The condition should be given for all items entered. It is assumed that all unserviceable items are scrapped at time tools are placed in storage (see 5-ab).

(n) *Material.* This term will be interpreted literally, and will be used in connection with patterns and high-speed cutting tools.

Patterns will be indicated as being of wood, metal, or metal-faced, as may properly apply to the item in question.

Cutting tools, when known to be made of high-speed steel, will have notation entered under this heading as "H. S. S."

This information will be given in all cases for patterns and for cutting tools when made of high-speed steel.

(o) *Description and Function.* This term should also be given the liberal interpretation, and sufficient description given to indicate clearly the character of the equipment and the particular use made of same, as, for example, if several jigs were used in the production of the same component, one being used for the top, another for the side and one end, and another for the bottom, the fact that each was a jig should be indicated to avoid possible confusion with some other class of equipment, and the particular purpose for which used stated to distinguish it from other jigs used on the same component. The description and function will be stated in the case of all equipment entered.

(p) *Operation Number.* The term operation number is used in designating the sequence of the various operations on a component in the course of manufacture, but in the case of the manufacturing equipment to which this record pertains, is by no means uniform or complete. However, it has a certain value in connecting various items of equipment with each other and for possible future use in connection with engineering and other records, and will be given in this record to such extent as the information now available at Rock Island Arsenal will permit.

(q) *Type and Size of Machine Used On.* This term has reference to the kind of machine tool, drop hammer, press, or other major piece of machine-shop equipment in conjunction with which the various items listed in this record were designed to be used, as, for example, a certain milling fixture might be of such size or form that it could not be used upon a milling machine of other design or size than the kind for which it was originally designed, in which case it is very essential to have information as to the type and size of machine used on.

There are a great many items which, with little or no material alteration, could be used on the ordinary machine-tool equipment of any average machine shop, and in such cases it will not be so essential to give information under this heading, but, in general, where the information is available, it should be given for all items.

(r) *Additional Equipment From.* The term will be interpreted literally, and under this caption will be shown the name of any contractor or contractors, other than noted after caption "Contractor," who were engaged on a similar project and who, upon the termination of their contracts, turned in the manufacturing equipment. As the methods used by various contractors in the production of similar components differed materially, it is not considered practical to combine the records of all equipment for the same project, and the notations indicating additional equipment to have been turned in by another manufacturer will at once guide the person consulting the record to another file in case the equipment for the particular component listed from one contractor may not suit his requirements.

Entry under this heading will be made on all *first sheets*, and in case only one contractor turned in tools, the word "none" will be used.

(s) *Remarks.* Space under this heading has been provided in two places on the record sheet; the first to be used for the purposes referred to in Paragraph 5, sub-paragraphs "l" and "m," and for such additional notations as may be considered essential in specific instances where some unusual peculiarity of the item may make further description advisable. The second space is provided for information pertaining to any subsequent inspections of equipment; for example, if equipment is drawn from the central tool storage for use in the shops in making up spare parts, upon their inspection and return to storage, notation will be made as to the accuracy of the equipment, or in case it is worn to such an extent as to be capable of but little further use, the notation should show approximate percentage of serviceability compared with new equipment; likewise, if revision of component drawing has been made, notation should indicate whether equipment is still serviceable or rendered obsolete by such changes. In general, under this heading will be entered information pertaining to serviceability of equipment based upon actual inspection.

(t) *Date Original Production Ceased.* This term as used herein has reference to the date on which the contractor completed, or for other reasons stopped, production on a project or component parts thereof.

for which manufacturing equipment used thereon was subsequently turned over to the Government. It will be understood to indicate that equipment is assumed to be serviceable and accurate for the production of the component on which it was used as of the date original production ceased. In this connection it should be understood in future use of record that where entries are made under inspection record headings, showing that the equipment has passed satisfactory inspection at a later date, the latest date shown will always be considered correct. In cases where such inspection has been made prior to the compiling of this record and the proper notation can be made at the time of compiling same, it will not be necessary to note the date original production ceased.

If sufficient information regarding the date mentioned above is not now available at the arsenal, the information will be furnished by the Ordnance Office, Tank, Tractor and Trailer Division, Washington, D. C., upon request.

Entries will be made under this heading on first sheets only.

(u) *Location of Equipment.* This term used herein is understood to have reference only to the arsenal or other authorized storage points at which the equipment is stored at the time of preparing this record, and the name of *Storage Point* will be written immediately following this heading. It is not intended in any way to give the storage location within the arsenal; neither is it intended that entries should be made of change of location in cases where the arsenal for any reason should send the equipment for temporary use outside the arsenal proper so long as the arsenal still retains accountability for same; in all cases, however, where notation is made of one arsenal after "Location of Equipment" and equipment is transferred indefinitely to another storage point which is to become accountable for same, or in case of a loan of equipment to a manufacturer involving a transfer of accountability, proper notations under the several headings pertaining to location will be made. The actual location of equipment stored within Rock Island Arsenal, or other storage point, will be kept on Central Tool Storage Records Cards (R I A Form 104). This information will be given for all items of equipment listed.

(v) *Date.* This term as used in this record under the section captioned "Location of Equipment" will refer to the date shown on shipping ticket upon which equipment is received at, or shipped from, the arsenal or other storage point. The date as above referred to will be shown for all items originally entered on this record and subsequently; as when making entries of change of location, as mentioned in preceding sub-paragraph (u).

(w) *Reference.* Used herein means papers bearing upon the receipt or shipment of property, and more specifically will refer to shipping tickets, which will be identified by the number written on the particular ticket covering the item in question. Notation under this heading will be made for all items entered.

(x) *From or To.* Under this heading will be written either the word "From," followed by the name of actual consignor, or the word "To," followed by the name of consignee, as may conform to the facts concerning the item. Notation will be made under this heading for all items recorded.

(y) *Received.* This is given a literal interpretation, and under this heading will be noted the actual number of pieces of identical equipment received and stored. It is to be understood that such equipment as, upon preliminary inspection preparatory to storage, is found to be unserviceable, or for other reasons is salvaged, is not to be included in the quantity noted under this heading. A proper notation under this heading will be made for all items carried on this record.

(z) *Issued.* This term as used herein will be understood to mean "dropped from the stock of the arsenal;" this may be by reason of shipment and transfer of accountability, or on account of equipment becoming unserviceable or obsolete. In the case of shipment and transfer, this fact will be clearly indicated by the notation made under "From" or "To," and if dropped on account of becoming unserviceable or obsolete, will be readily determined by notation made under "Remarks" (Inspection Record). The number of pieces of any particular item of equipment issued as understood from the above explanation will be noted from time to time as such issue occurs.

(aa) *Balance.* This will mean the total quantity of equipment of an identical kind and tool symbol on hand in the Ordnance Department; for example, six identical items are received noted under heading "Received," this would also be the entire quantity of that particular kind and symbol on hand, and is therefore shown as (6) under heading of "Balance," later four additional tools of same symbol are received, (4) being noted under heading "Received," and the total (6 plus 4) or 10, shown under heading "Balance;" subsequently three tools are shipped from storage at Rock Island Arsenal to Watertown Arsenal, and accountability transferred—the notation (3) is placed under heading "Issued," but the figure 10 is left unchanged in the column under "Balance" for the reason given below:

Rock Island Arsenal is to be the central point for all manufacturing equipment for tank, tractor and trailer vehicles, except equipment used in connection with armor plate, which will be stored at Watertown Arsenal. Rock Island Arsenal will drop actual property accountability when making transfers to other arsenals, but the equipment transferred will continue to be available within the Ordnance Department at the location noted under heading "From" or "To," and when it has served the purpose at the point to which transferred, must be returned to Rock Island Arsenal if serviceable. In making transfers of manufacturing equipment, the consignee should be advised that as soon as equipment has served the purpose for which it is transferred it must be returned to Rock Island Arsenal, and that in all cases where the period for which the equipment is held exceeds three months, a report of all items of equipment becoming unfit for further service during that time must be made to Rock Island Arsenal, and further reports submitted every three months thereafter until the equipment is either returned to Rock Island Arsenal or worn out in service and dropped from stock.

Proper entry will be made on the manufacturing equipment record from the information given on the reports mentioned above.

A suitable follow-up system should be devised by Rock Island Arsenal to insure the ultimate return to Rock Island Arsenal of all serviceabe equipment.

(ab) *Inspection Record.* This term is used only as a general caption

MANUFACTURING EQUIPMENT RECORD

PROJECT _____ GROUP OR ASSEMBLY _____ SHEET NO. ____ OF ____ SHEETS

ORDNANCE COMPONENT SYMBOL _____ NAME OF PART _____

ORDNANCE DRAWING NO. _____ DATE ORIGINAL PRODUCTION CEASED _____

CONTRACTORS COMPONENT SYMBOL _____ CONTRACTOR _____

ADDITIONAL EQUIPMENT FROM _____

	TOOL SYMBOL	TOOL DRG. NO.	QUAN TITY	CONDITION	MATERIAL	OPER ATION NO.	DESCRIPTION AND FUNCTION	TYPE AND SIZE MACHINE USED ON
1								
2								

REMARKS

LOCATION OF EQUIPMENT ---------- INSPECTION RECORD

	DATE	REFERENCE	FROM OR TO	RECD	ISS'D	BAL.	DRG. REVISION	DATE INSPECTED	REMARKS
2									

Fig. 1. Layout for Blank form "Manufacturing Equipment Record"

for that portion of the record pertaining to information bearing upon the serviceability and accuracy of equipment.

There are approximately 75,000 pieces of equipment at Rock Island Arsenal about 7,000 pieces additional now loaned in connection with current contracts, and possibly 2,000 pieces pertaining to armor plate at Watertown Arsenal, and for the reason that much of this equipment will probably become obsolete by reason of the development of newer types of material before another emergency may arise, it has been decided that the expense incident to an inspection for accuracy of all this equipment would not be justified. There are a large number of pieces, however, which will be used from time to time in the manufacture of spare parts, and it is also reasonable to assume that as some improvements are made in present designs of material, and such equipment is used in manufacture; much will remain serviceable for several years.

The purpose of the inspection record is to have available in convenient form for quick reference, data which will make it possible to determine whether or not equipment can be used. As a basis for use in this connection, it will be assumed that unless specifically noted otherwise, all equipment entered upon this record was serviceable as shown under "Date Original Production Ceased;" any information obtained by check of equipment with later drawings will be noted under the headings "Drawing Revision," "Date Inspected," and "Remarks."

In general, entries will be made on the inspection record as the inspection of equipment is made for use in the shops; for example, it will be assumed that an order has been placed with the arsenal to manufacture a number of parts of a certain revision date; inspection of the equipment will be made to see that the tool is suitable for use in making the component ordered, and if the tool is found suitable for use the revision date of the drawing, in accordance with which the piece is ordered, will be entered in the drawing revision column and the date of the inspection under "date inspected." In case there should be several pieces of identical equipment, and the drawing revision made it necessary to make alteration to the equipment to render it serviceable, it may happen that on account of the small number of components ordered, only one or two of the several pieces of equipment are changed to the latest revision, in which case the number of pieces so changed should be noted under the column "Remarks."

(ac) *Drawing Revision.* This term is used to indicate that a change has been made to a drawing subsequent to the original date of issue of same; for example, a drawing issued June 10, 1918, would be so dated: a change is made August 9, 1918, and this date is also shown on drawing; another change November 1, 1918, is made, and this date also shown on the drawing, the revisions being referred to as "Revised 8-9-18," and "Revised 11-1-18." Explanation of use of this heading is made in sub-paragraph "ab."

(ad) *Date of Inspection.* This will refer to the date on which the last inspection of equipment is made. Explanation of use of this heading is made in sub-paragraph "ab."

All *Manufacturing Equipment Record Sheets* will be filed in substantial post binders in the following manner: (a) Reference will first be made to project, and record of all equipment pertaining to each project (unless found inconvenient on account of bulk) will be placed in one binder. (b) Records will be kept separate with reference to the contractor turning in the equipment covered. (c) The sheets of the record will be filed with reference to the ordnance component symbol in numerical sequence; thus, in the case of the 6-ton special tractor, record of all equipment pertaining thereto would be in one binder, which should be plainly marked on the outside, and this binder would be further separated into three (3) sections marked, respectively, "Maxwell Motor Co.," "Van Dorn Iron Wks. Co.," and "C. L. Best Gas Traction Co.," the three contractors who worked on this project.

A small circle is printed on the upper right-hand corner of each sheet, in which, for convenience in filing, will be inserted the component symbol number to which the equipment listed upon the sheet pertains.

In the case of some projects where there was only one contractor on each, and when the total quantity of equipment is not large, there will be no objection to filing more than one project in a binder, provided the binder be marked to indicate the fact and the records are properly separated therein.

With reference to the preservation and filing of drawings, tracings and prints of tools, jigs, and fixtures, it has been decided to have these retained at Rock Island Arsenal; the method of filing to be as follows:

(a) Drawings, etc., will be folded to the approximate size of 10 inches by 14 inches (11 inches by 14½ inches being maximum); the inked or printed face in all cases being folded in to protect from light.

(b) After folding, the sheet will be legibly marked on the upper right-hand corner with (a) the *Project* to which the tool equipment pertains; (b) with the name of the *Contractor* from whom the equipment was turned in; (c) the *Ordnance Component Symbol* of the part to which equipment pertains; (d) the *Drawing Number* of the tool drawing as appearing thereon.

(c) Drawings will be filed in legal size filing cabinets by ordnance component symbols in their numerical sequence for each project, making a separate file for each contractor.

For the purpose of filing, use is not made of the actual number of the tool drawing, but *tool drawing numbers* will, whenever tool drawings are available, be shown on the manufacturing equipment records, which also show *project*, *contractor*, and *component symbol*, making a complete index, by reference to which any drawing may be readily located.

The value of engineering data pertaining to the manufacture of tank, tractor and trailer material is appreciated, but the funds necessary for working up such data into the most desirable form are not available at this time, therefore work along this line will be limited to that of merely filing and preserving in the form existing. Data available consists of route sheets, index cards, inspection data sheets, specification of material, O. O. Form 5817, records of weights of various component parts, and miscellaneous information, the extent and form of data differing considerably for the different projects.

Folders will be used where practicable, and plainly marked on the upper right-hand corner with (a) *Project* to which contents pertain; (b) *Contractor* to whose methods of manufacture the data pertains; (c) brief *Index* as to nature of data contained in folder. In the case of index cards, these will be securely tied in such manner as to prevent damage or loss, and will have attached either a tag or card plainly marked with the same information as in the case of folders.

With reference to *Filing*, *Project* and *Contractor* only will be considered and locationed in file made in accordance therewith as outlined for filing of tool drawings. No reference is made to engineering data on manufacturing equipment records, but a sheet will be filled out and inserted in the manufacturing equipment records for each contractor on each project, stating whether or not any engineering data pertaining thereto is available, and of what it consists.

It is intended that these records shall be as complete and accurate as possible, and they are planned with the idea of having entries made from time to time at the arsenal after their compilation, so that at intervals of time hereafter to be designated by the Ordnance Office, Tank, Tractor and Trailer Division, blue prints may be made from them and forwarded to that office, Washington, D. C., thus providing accurate, up-to-date information at a minimum of work and expense.

Procurement of Military Supplies

Arrangements are being made for an organization in the office of the Assistant Secretary of War to carry out that section of the army reorganization act of June 4, 1920, that charges the Assistant Secretary with supervision of procurement of all military supplies and other business of the War Department pertaining thereto and the assurance of adequate provision for the mobilization of material and industrial organizations essential to war-time needs.

Practically nothing was done toward carrying out that portion of the law by the last administration, although a general order was issued August 12 last, defining the duties of the Assistant Secretary of War, and charging him specifically, among other things, with "the compilation of statistical data and the formulation of the necessary plans for assuring adequate provision for the mobilization of material and of the industrial organizations of the country essential to war-time needs."

With the advent of the new administration and appointment of Jonathan M. Wainwright as Assistant Secretary of War, plans for assuring adequate supplies of war materials in time of emergency have been given serious consideration, with a view of carrying the law into effect, in order that plans and other preparations may be made, so that the delays that ensued in the last war in bringing industrial plants into co-ordination with the government and putting them on a basis of quantity production of war material may be avoided in the future.

For that purpose a section is being organized in the office of the Assistant Secretary, and its duties perhaps will be the most important and valuable to be performed under his jurisdiction. The executive officer of the section is Col. John S. Fair, of the general staff, who has as his principal assistant Col. Harley B. Ferguson, of the corps of engineers. The law authorizes the detail to the office of the Assistant Secretary from the branches of the army engaged in procurement such number of officers and civilian employes as may be authorized by the Secretary of War. In accordance therewith one officer will be detailed to the section from the quartermaster corps, medical department, corps of engineers, ordnance department, chemical warfare service, signal corps and air service. Col. Morgan L. Brett already has been detailed from the ordnance department, and tentative selections have been made of representatives of other branches.

Voluminous records pertaining to the methods employed in co-ordinating industry with the government during the war are on file, and they show the methods employed and disclose the errors made. Among the most valuable of them perhaps are those of the Council of National Defense, which will be available to the office of the Assistant Secretary of War, of course. An immense amount of statistical data and other information also has been accumulated in the historical, statistical and other divisions of the various branches of the army. —*Washington Post.*

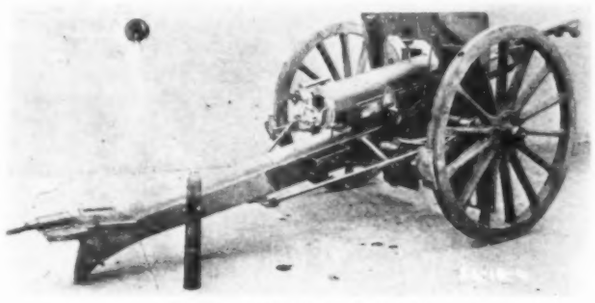
"Seventy-Five" *vs.* "Soixante-Quinze"

A Comparative Study of American and French Divisional Artillery

By

D. A. GURNEY
Member A. O. A.

THE 75-mm. Gun Carriage, Model of 1897 (French), used by the French and American armies during the war, and familiarly known as the Soixante-Quinze, is quite generally reputed to have been the best type of field artillery weapon then in use. This favorable reputation is believed to be due principally to the fact that the hydro-pneumatic recoil mechanism used on this carriage was more reliable than the hydro-spring mechanism used on the British and German field carriages, and the single-trail axle traverse carriage is simpler to operate and repair and cheaper to construct than the split-tail type, as used on the Italian Deport and on our 75-mm. Gun Carriage, Model of 1916.



The French "Soixante-Quinze"

Aside from the manufacturing difficulties experienced with the recoil mechanism of this carriage, which are quite generally understood and have been discussed in detail elsewhere, the carriage proper is not an easy manufacturing proposition. This carriage was manufactured in this country in quantity during the war, and great difficulties were found and overcome in the manufacture of the trail, which is not of simple form, and in the manufacture of the rockers and operating mechanisms.

At the close of the war an attempt was made by the Westervelt Board to obtain a consensus of opinion of the artillery officers of the various countries as to what should constitute an up-to-date carriage for the light field gun. Opinion was not at that time definitely crystallized, but all the nations had experimented to a varying degree in trying to develop a carriage having greater elevation and increased range and a wider field of traverse. As a result of its investigations the Westervelt Board drew up specifications for an ideal gun which should be about 3 inches in caliber with a maximum range of 15,000 yards, a vertical arc of fire from minus 5 to plus 80 degrees, and a horizontal arc of fire of 360 degrees, and stipulated that if practicable the carriage should be designed to mount either the light field gun or the light field howitzer interchangeably. These specifications were accepted as the basis of the design of the 75-mm. Gun and 105-mm. Howitzer Carriage, Model of 1920, which fulfills all the requirements of the Caliber Board specifications except for traverse, the total traverse obtained on this carriage being 30 degrees. The 360-degree traverse can only be obtained on a pivot mount, and seems impracticable for any conventional type of carriage to be drawn by horses. Four of these carriages, two mounting the 75-mm. field gun and two mounting the 105-mm. howitzer, have already been completed, and will soon be tested at Aberdeen. The total weight of the gun, carriage and limber is about 4,800 pounds, which is considered too great for this type of artillery.

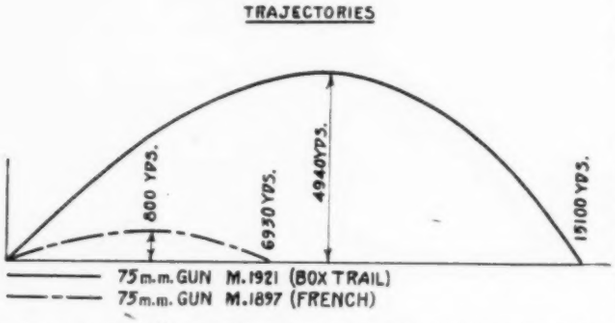
As an alternate to the split-trail carriage above referred to, design of a single trail carriage, Model of 1921, for a 75-mm. gun of the same ballistics as the 75-mm. gun, Model of 1920, has been completed and one carriage is now under manufacture, which will be available for test this coming

The New American "Seventy-Five"

summer. This carriage has been designed with the idea of making it as light and as simple to manufacture as possible and it is expected that the total weight of the gun, carriage and limber behind the team will not be more than 4,000 pounds.

The gun is known as the 75-mm. Gun, M. 1920MII, is 42 calibers in length, fires a shell weighing 15 pounds to a range of 15,100 yards with a muzzle velocity of 2,175 foot seconds, this velocity being obtained with a supercharge. The normal charge for this gun will give a velocity of 1,500 foot seconds. The weight of the shrapnel is 17 pounds; the shrapnel velocity has not yet been definitely decided upon. The gun, of chrome steel, is provided with a breech mechanism of the horizontal sliding type, and weighs 945 pounds.

The recoil mechanism is hydro-pneumatic of the St. Chamond type, the length of recoil being constant—42 inches. Due to the fact that the elevation has been limited to 45 degrees, and due to the location of the trunnions, which are situated at the rear end of the cradle just in front of the breech, it has been found practicable to use constant recoil, thus reducing the size of the cradle materially as compared with the 1920 model, with consequent reduction in weight and greater simplicity. A spring



The New American "Seventy-Five" has twice the range of the French "Soixante-Quinze"

equilibrator is provided underneath the cradle, which is designed to overcome the unbalanced moment of the tipping parts, thus providing comparatively light handwheel loads. The carriage is provided with the independent line of sight, which is accomplished by means of rockers, one on either side of the cradle pivoted at the trunnions. These rockers carry large spur arcs at their forward ends. Pinions carried by the cradle mesh with these arcs, and are rotated by means of an elevating handwheel situated on the right side of the carriage near the range drum. By rotating this handwheel the carriage is brought to the proper elevation for range. A second pair of spur pinions mounted on a shaft located in the trail very nearly underneath the trunnions mesh with these same arcs. This shaft and pinions are rotated by an angle-of-site handwheel situated on the left side of the carriage. By rotating this handwheel the rockers are leveled when indirect aiming is employed or they are used to lay the sight on the target under the condition of direct fire. The standard panoramic sight is mounted on a bracket located on the left trunnion, and is provided with a cross level for correcting the azimuth error due to difference in level of the wheels.

The carriage is provided with axle traverse, which is obtained by shifting the front end of the trail transversely along the axle by means of a screw and nut operated by means of a traversing handwheel situated on the left side.

The axle is of simple I-beam section, except for the axle arms, which are of standard design. The wheels are 48 inches in diameter, having 3½-inch solid rubber tires. Standard 56-inch wheel hubs and standard spoke shoes are provided. The estimated weight of each wheel is about 230 pounds.

The trail is constructed of 2 flasks which are of box section, the flanges being formed in such a way that no inside riveting is required. The flasks are perfectly straight from axle to spade, and are tied together near their front ends by the bracket which supports the angle of site pinions, and at their rear ends by the spade and tool box. Near the front end of the trail, triangular-shaped brackets for supporting the trunnion bearings are riveted, and the trail is provided with the customary seats for the cannoneers who operate the elevating and traversing mechanisms. No axle seats are provided. Band brakes, operated on brake drums carried by the wheels, are controlled by means of a brake line, which extends to a point near the rear end of the trail and is operated through small cables by a cannoneer seated on the carriage limber.

The main shield is secured to the trail and to the brackets supporting the trunnions. A folding apron is situated underneath the trail, and a top shield, whose position is controlled by means of hinges operating on the automobile windshield principle, is provided. This top shield is so arranged that it may be folded down over the panoramic sight hood, thus permitting the use of aiming points throughout 360 degrees of azimuth.

It should be understood that although the 75-mm. Gun Carriage, M. 1920, as designed weighs about 800 pounds more than the expected weight of the M. 1921 carriage, a great deal of this excess weight can be eliminated by a proper redesign. The split trail carriage is really a carriage for the 105-mm. Howitzer, and it is estimated that by using the same gun and cradle as is used on the box trail type and limiting the elevation to 45 degrees, a split trail carriage can be designed having 30 degrees or more traverse whose weight will be not more than 300 pounds over that of the box-trail type.

A tabulation showing the various characteristics of the 75-mm. Gun materiel, Models of 1897, 1920 and 1921, follows:

	75-mm. Gun M. 1897 (French)	75-mm. Gun M. 1920 (Split Trail)	75-mm. Gun M. 1921 (Box Trail)
Length in calibers	34.5	42	42
Muzzle velocity, shell, normal f.-s.	1,805	1,500	1,500
Muzzle velocity, shell, super f.-s.	----------	2,175	2,175
Muzzle velocity, shrapnel f.-s.	1,755	not determined	
Maximum range at elevations obtainable on carriage yds.	6,930	**15,100**	**15,100**
Maximum elevation possible	8°	30°	10°
Maximum traverse (total) on carriage	19°	80°	45°
Weight of shell lbs.	12.2	15	15
Weight of shrapnel lbs.	16	17	17
Normal length of recoil inches	47	40–48	42
Weight of gun and breech mech. lbs.	1,015	1,242	945
Weight in firing position lbs.	2,887	3,600	2,800
Weight of gun, carriage and limber lbs.	4 411	4,800	4,000

Final Drive for Combat Vehicles

By

G. R. PENNINGTON and S. K. WELLMAN

Members A. O. A.

INASMUCH as the track-laying tractor is essential for motorizing field artillery, it is believed that the following study of certain steering mechanisms for such tractors will be of general interest.

It is proposed to compare the relative advantages of four types of steering mechanisms as follows:

Differential Type (Figure 1).

In this type the driving sprockets of the two tracks are connected through a differential which is driven by the motor in a manner exactly similar to automobile rear-axle construction. Separately controlled brakes are mounted on the two shafts, and steering is accomplished by applying the brake on the side toward which the tractor is to be turned. Hereinafter this type will be briefly referred to as the "Differential."

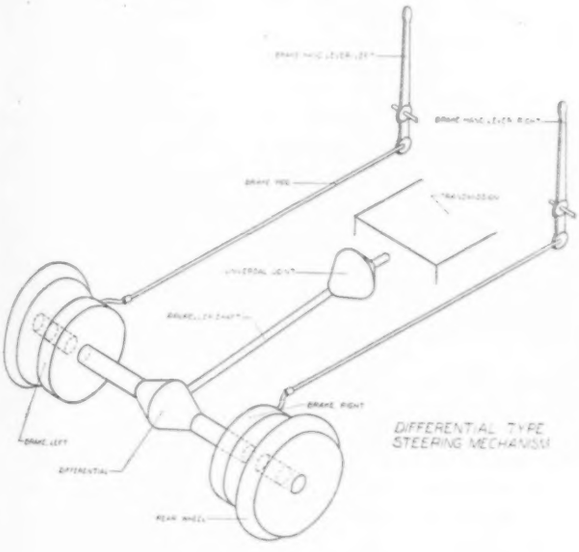


Fig. 1.

"Planetary"—Fixed Ratio Differential Type (Figure 2).

In this type planetary gearing is applied to the differential in such a way that when a brake is applied on the planetary system the two sides of the differential and, consequently, the two tracks are driven at a fixed speed ratio to each other. A brake on one side turns the tractor to the right and a brake on the other side turns the tractor the other way. Hereinafter this type will be therefore referred to as the "Planetary."

"Holt"—Separate Clutch-Drive Type (Figure 3).

In this type a separate clutch is applied to the drive to each track so that the power may be applied to one side only when desired. Separately controlled brakes are in addition provided to produce turning. The 5 and 10 ton artillery tractors are of this type. As these were derived from the original Holt tractors, this type will hereinafter be referred to as the "Holt."

Selective-Speed Type (Figure 4).

In this type either track may be driven independently of the other at either of two selective speeds, brakes being provided likewise to act independently on each track.

The model 1920, 2½-ton artillery tractor is of this type. In this tractor two clutches are mounted on each of two shafts which drive the two tracks. One of the clutches on each shaft is for high speed and the other for low speed. By engaging both high speed or both low-speed clutches the speed of the tractor as a whole is controlled. By engaging one high-speed and one low-speed clutch the tractor turns on a fixed radius towards the side in low. By engaging either clutch on one side and applying the brake on the other, the tractor will turn on the other side as a fixed pivot. For the sake of brevity this type will hereinafter be referred to as the "2½-ton."

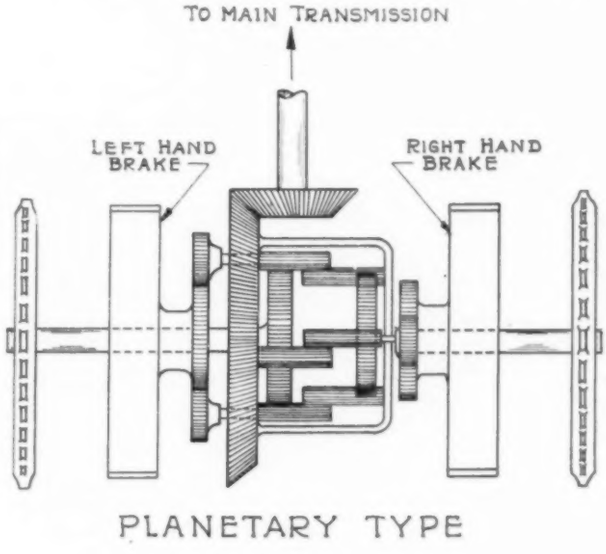


Fig. 2.

In order to simplify the comparison of the four types of steering mechanisms, four tractors will be assumed to be of equal weight, having identical motors, running at the same speed and torque, identical total gearing reductions and identical efficiencies, but with the four different types of steering mechanisms under consideration. These tractors will be referred to as above noted as the "Differential," "Planetary," "Holt" and "2½-ton."

The action of these tractors will be compared from the standpoint of:

1. Variation of tractive force.

This is defined as being the force exerted by the tracks against the ground. (The draw-bar pull being equal to this force less the force needed to move the tractor itself).

2. Ease of control.

The following possible conditions are considered:

(A) When running straight ahead.
(B) When running on a large radius.
(C) When turning on a short radius.
(D) When turning with one track stationary.

Variation of Tractive Force

(A) *Running Straight Ahead.*

1. The four tractors will obviously travel at the same speed, and exert the same tractive force on even dry ground. If, however, one track is in a mudhole, and the other track only has traction, the result will be as follows:

2. On the Differential and Planetary, the track which has no traction will slip, and the other track will receive no driving force except that caused by internal friction.

Note.—This effect can not be overcome by the use of a locking differential as in a Nash Quad, for the reason that the steering depends on the free action of the differential. If high internal friction gives partially the effect of a locking differential, this high friction will cause loss of power in turning. The only remedy would be a positive lock, which would not be convenient.

3. On the Holt and 2½-ton tractors, the track having traction will take the entire torque from the motor. In this respect the Holt and 2½-ton have an important advantage over the Differential and Planetary tractors.

(B) *Turning on a Wide Radius (as in ordinary road steering).*

1. In the Differential and Planetary tractors it is necessary to apply the brake on the drive to the inside track, which results in a dissipation of power in the form of heat. The amount so lost in the Planetary is less than that lost in the Differential, because in the former a part of the braking force is returned to the outside track through the planetary train.

2. In the Holt and 2½-ton the clutch to the inside track is disengaged, and the drag of the load produces the necessary turning.

Note.—This is not true altogether when the tractor is running on a good road, or without load, but at such times there is no disadvantage in applying the brake to produce turning. At times when the tractor is straining its utmost to pull up a steep grade, or through soft ground, the tractor will turn as described without the necessity for applying the brake with consequent loss of power.

3. When turning on a wide radius, the Holt and 2½-ton tractors thus have an advantage over the Differential and Planetary tractors. This advantage, while small, would appear at the moment when maximum power was called for, and would permit the Holt or 2½-ton tractor to take a turn on a steep hill which would just stall the Differential or Planetary tractors.

(C) *Turning on a Short Radius* (which is taken equal to the Planetary's shortest turning radius and the 2½-ton's turning radius with one high speed and one low-speed clutch engaged).

1. In the Differential tractor it is necessary, as it was in a turn on a wide radius, to apply a brake on the drive to the inside track with consequent loss of power dissipated in the form of heat.

2. In the Planetary tractor the brake on the drive to the inside track is locked and consumes no power, the braking force being transmitted through the planetary gears to the outside track with only such loss as is incident to the operation of the differential gears.

3. In both the Differential and Planetary the outside track is accelerated by the same amount that the inside track is retarded. This is equivalent to reducing the gear ratio from the engine to the outside track, and since this is the track which does the driving, the effective gear ratio of the tractor is reduced. This means that at the moment when the most tractive force is needed to overcome the lateral resistance to turning there is the least available.

4. The Holt tractor turns by braking on one side with consequent loss of power, but the outside track receives the full power of the engine, and at the same gear reduction as in straight running. The tractive force is, therefore, the same as in straight running.

5. As between the Planetary and Holt, we have, therefore, the greater efficiency of the former offset by the more effective ratio of the latter. The degree in which these factors will offset each other will depend upon road conditions, and can not be stated definitely. It is safe to say, however, that the practical difference in tractive force is not great.

6. The 2½-ton turns by driving one track at the high-clutch speed and the other track at the low-clutch speed. Any retarding force necessary on the inside track to cause turning is transmitted through the gearing to the other track without appreciable loss. The gear ratio from the engine to the outside, or driving, track remains the same as in running straight ahead.

7. The 2½-ton thus combines the advantages of both the Planetary and the Holt when turning on a short radius, and can deliver a greater tractive force than any of the other three tractors.

(D) *Turning with One Track Stationary.*

1. In the Differential tractor this can be accomplished with a loss of only such power as is required to rotate the differential gears. The gear ratio from the engine to the outside, or driving, track is, however, reduced to one-half that of straight running, and the tractive force is therefore reduced below half that of straight running.

2. The Planetary tractor can not turn with one track stationary.

3. In the Holt and 2½-ton, no power is lost internally, and the full torque of the engine is transmitted to the outside, or driving, track at the same gear reduction as in straight running, and the tractive force is the same as in straight running.

4. The Holt and 2½-ton can therefore exert more than twice the tractive force of the Differential when turning with one track stationary.

5. Furthermore, the Holt and 2½-ton have an important advantage over the Planetary, as the latter can not turn at all with one track stationary. This advantage appears when it is necessary to move a very heavy load. The Holt or 2½-ton can lock one track and apply the full tractive force to the other track. As the draw-bar is midway between the two tracks, it receives this tractive force multiplied by the ratio of the lever arms from the pivoted track, with the effect of approximately doubling the drawbar pull. By alternately locking first the left and then the right-hand tracks, and throwing the power to the other tracks, the Holt or 2½-ton will be able to pull a heavier load under difficult conditions than the Planetary could move.

Summary (variation of tractive force).

1. The Differential tractor is inferior to at least two of the other three tractors under each condition considered.

2. The Planetary tractor in straight running will lose

tractive force if one track slips. On a long radius it is second to the Holt and 2½-ton. On a short radius it may or may not excel the Holt, but will not equal the tractive force

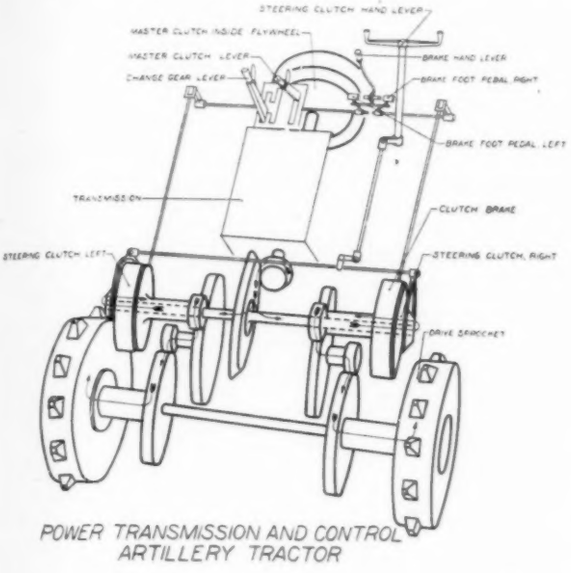


Fig. 3.

of the 2½-ton. It's inability to turn on a fixed radius makes it unable to pull as big a load as the Holt and 2½-ton in emergencies.

3. The Holt tractor will pull a heavier load over difficult terrain than either the Differential or Planetary tractors.

4. The 2½-ton tractor will equal the Holt tractor under all circumstances, and will deliver a greater drawbar pull on all turns which require a positive braking action on the inside track and which have a radius not less than that of the 2½-ton with one high and one low-speed clutch engaged.

Ease of Control

(A) *Running Straight Ahead.*

1. The Differential and Planetary depend upon the balance of forces within their differentials to keep them running on a straight line. When, therefore, inequalities of the ground put more resistance in the way of one track then the other, this balance is destroyed, and the tractors will turn towards the side where greatest resistance is encountered. This tendency is very evident in commercial tractors of this type when plowing, as the operators must manipulate the steering gear frequently to keep them running in a straight line.

2. In the Holt and 2½-ton the two tracks are positively driven at the same speed, and these tractors therefore have no tendency to turn from a straight line.

(B and C) *Turning on a Large or Small Radius.*

1. The four tractors would handle with practically the same ease, provided that in the design of the controls the possibilities of the respective mechanisms were developed to an equal degree.

(D) *Turning with One Track Stationary.*

1. This can be accomplished readily with any of the tractors except the Planetary.

2. The fact that the Planetary can not turn with one track stationary is a disadvantage worth considering, as the ability to so turn is a great help in manœuvring in close quarters, and when hooking up to a vehicle which is to be towed.

Summary (Ease of Control).

The Holt and 2½-ton would have an advantage over the Differential and Planetary due to their natural tendency to run straight ahead without requiring any effort on the part of the operator.

The 2½-ton has an added advantage in that it can be started on low, thrown into high, turned on a wide radius

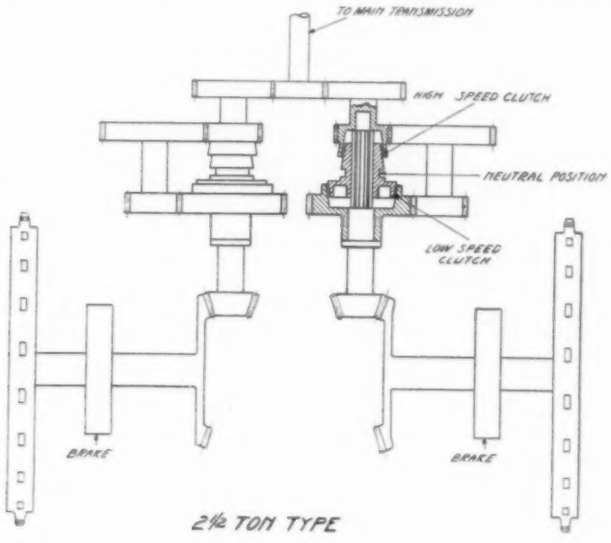


Fig. 4.

when manœuvering in close quarters, stopped and brakes locked without requiring the operator to remove his hands from the controls. The 2½-ton has therefore a more flexible control than the others.

Conclusion

It is the opinion of the writers that for military service the Holt steering mechanism is the most suitable of those considered for heavy and relatively low-speed tractors, and the 2½-ton mechanism is the best for light and relatively high-speed tractors. The Planetary mechanism is believed to take third place for either character of service. The Differential mechanism should not be considered at all.

M. I. T. Course for Ordnance Officers

The Ordnance Department has just completed arrangements with the Massachusetts Institute of Technology whereby a special course of one year will be conducted for officers of the Ordnance Department. This course starts with a review of advanced mathematics and applied mechanics, includes in it subjects given in the regular courses offered by the Institute in machine-tool design heat engineering, electricity, and special courses in the following ordnance subjects:

Ballistics, Chemistry, Optics, Theory of Elasticity, Gun design and design of other ordnance material.

The Ordnance Department is pursuing the policy of holding a large part of its vacancies to be filled by transfer or detail from the line, since in this way the work of the department can be kept in closer touch with the point of view and requirements of the line, a contact which is essential but which will be more difficult to maintain as the proportion of appointments from civil life increases.

There will be a number of vacancies in the Ordnance Department after the appointment of the successful applicants who took the examination for appointment of second lieutenants from civil life April 25, so that applications for detail or transfer from officers of the line who possess the necessary qualifications will continue to receive favorable action.

Production and Inspection of Artillery Tractors

By

NORRIS W. OSBORN

Member A. O. A.

PRIOR to America's entrance into the World War, track-laying or caterpillar vehicles suitable for artillery purposes were being manufactured on a relatively small scale, and the manufacturers of vehicles of this type were not prepared to expand sufficiently in the limited time to produce the great number of vehicles required. Contracts, therefore, had to be let to other commercial organizations who were equipped to handle similar materials or who could, with slight modifications to their plant, adapt it to the manufacture of artillery tractors. On account of the food situation it was not considered advisable to interfere with the production of farm tractors and the automobile manufacturers were the next most logical producers of war tractors.

In September, 1917, there was an unanticipated demand from the A. E. F. for a tractor of about 9,000-pounds weight, which was not in production in the United States. As a result of preliminary tests of some old experimental vehicles at Rock Island Arsenal on November 9 and 10, 1917, the production of the 5-ton tractor was decided on. As soon as the general characteristics were determined, orders were placed with the Maxwell Motor Company of Detroit, Mich., and the Reo Motor Car Company of Lansing, Mich. The first drawings for the experimental vehicle were released on November 29, 1917, and the last drawings on January 17, 1918. Three days later, at the Maxwell Motor Company, a finished tractor was operated under its own power, demonstration of which indicated that the 5-ton tractor was to be a success.

Experimental 5-ton Artillery Tractor, built in 29 working days

In order to produce this entirely new design of tractor, it was necessary to design tools, jigs, fixtures, patterns and dies in order to go into production. Due to the weight of the vehicle and to its component parts being heavier than similar parts used in pleasure cars and trucks, it really meant overloading machinery intended for manufacturing pleasure cars and trucks, and required a very careful study of the equipment at the Maxwell and Reo plants to determine what additional equipment was needed. Additional machinery to handle the extra-heavy parts was procured, and the planning departments of both concerns laid out new assembly lines and general routing of parts to meet the requirements of the new product. This caused the rearrangement of the greater part of all machine equipment, the erection of new tool cribs and stock bins, and a complete new method of routing. The Maxwell and Reo Companies actually manufactured all production tools, jigs, fixtures, patterns and dies, but in order to guarantee actual interchangeability of parts between Maxwell and Reo made tractors, the gages were contracted for with gage manufacturers, the same manufacturer furnishing both companies with identical gages.

Extensive tests were carried out with the first experimental tractor, and, although it was of a new design, very few mechanical changes were necessary. The armor, which was rather cumbersome, and the driver's seat, which had not been placed to the best advantage, were practically the only two components to be redesigned. These modifications in no way affected production, and after the preliminary test, production drawings were released for tooling-up. The experimental tractors were given severe road tests that lasted for months after the drawings had been released for production, in order to determine whether or not there would be any defects that would be detrimental to the vehicles after they were issued to the service.

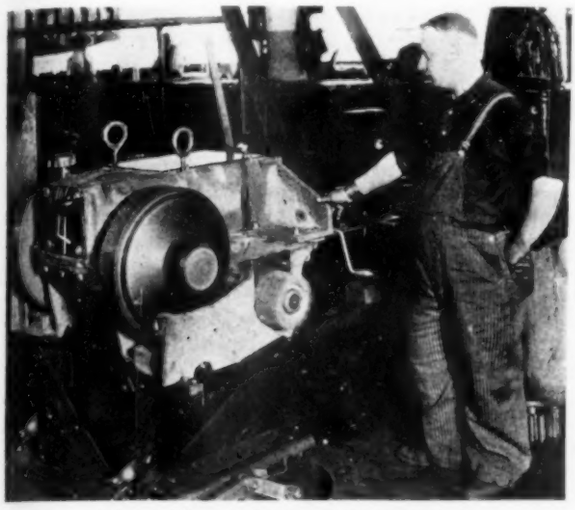
By June 1, 1918, the tooling-up was completed and sufficient material received so that production could be started. The first production tractor left the assembly floor on June 9, 1918, at the Chalmers Plant of the Maxwell Company, and shortly after this the first production tractor was completed at the Reo plant. The production rapidly increased at both plants, up to a joint production of 40 tractors per day in August and a maximum production of 62 on November 10, 1918.

When one familiar with factory practice considers the actual date that the design was started and approved by the Ordnance Department, and that so little was really known about artillery tractors, this is considered a remarkable feat, as the average automotive vehicle is several years under design and consideration before actually being put on a productive basis for the market.

In addition to contracts for 5-ton artillery tractors, the Maxwell Motor Company also had contracts for transmissions for the 10-ton artillery tractor as manufactured by

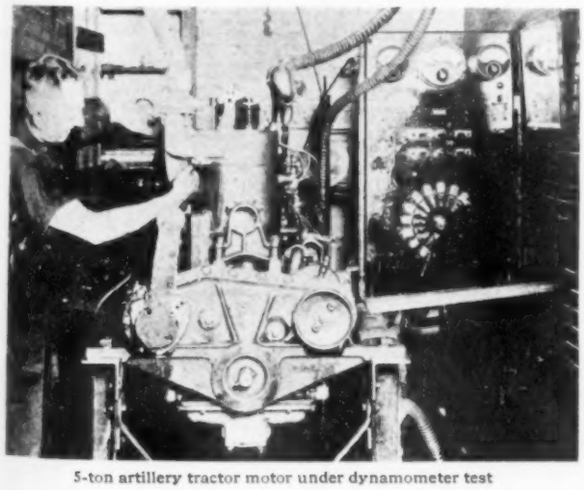
the Holt Manufacturing Company and the Chandler Motor Car Company, 6-ton tanks complete and miscellaneous 2½-ton artillery tractor parts.

"The vehicles, spare parts and accessories for which proposals are invited must conform in quality of material and workmanship and in dimensions and assembling to the requirements given on the drawings and in the specifications furnished by the Ordnance Department for the vehicles or



10-ton artillery tractor transmission under test

other articles under construction." This short statement, which is the first paragraph to "Instructions to Bidders," covers a vast territory when applied to a new commodity to be built on a large production basis. It was necessary to give the artillery tractors a 100 per cent inspection, as they were the first production tractors to be built, and accurate records were essential in order to gain sufficient engineering data to cover all future designs. All materials, such as bar



5-ton artillery tractor motor under dynamometer test

stock, castings and commercial parts, were inspected at the rolling mills, foundries or commercial parts factories, while all machine work and assembling was inspected at the prime contractor's plant. All material, regardless of what it was or where it came from, was checked through the receiving rooms of the contractor, and accurate records kept. Ordnance inspection is not based on mere inspection of materials nor to force a contractor to build a commodity in accordance with the specifications. The principle is to assist the contractor in the production of the commodity and act as the medium between the Ordnance Department and the contractor, the ultimate results being greater production, a more uniform article and the Government having complete records of each article for future maintenance and engineering purposes. In times of emergency, deviations from drawings and specifications must be made, and the Army Inspector of Ordnance is the negotiator between the contractor and the Government to see that the substitutions do not affect the serviceability of the article nor interchangeability of parts.

Civilian inspectors, each a specialist in his line, were hired by the various Army Inspectors of Ordnance inspecting artillery tractors. Parts inspection parallel to contractor's inspection was done primarily to catch mistakes which might hinder production later on if the parts were not held within the tolerances prescribed. The next step, and one of the most important, is the inspection of assemblies. A

Field testing tractors in summer

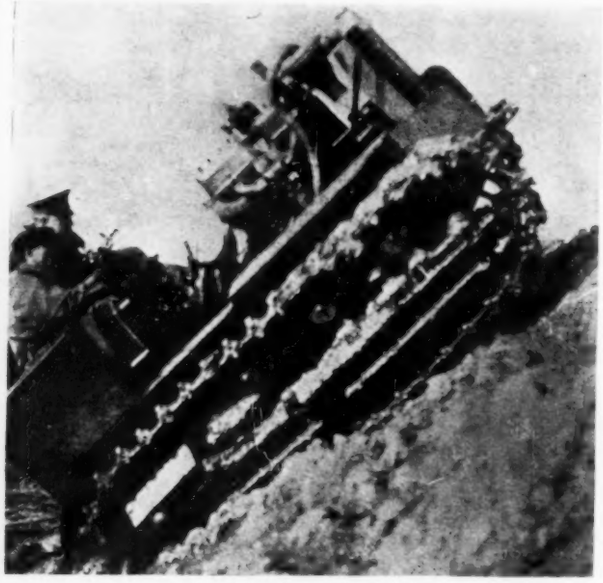
transmission for a 10-ton tractor weighs approximately 2,500 pounds, consists of 473 parts and has over 70 different points of inspection. A slight error in any one of 59 would destroy the proper functioning of the unit.

Transmissions were given detailed inspection on the assembling line and then run in on a stand at the prescribed load and speed, but prior to acceptance were run for 15 minutes at a 50 per cent higher speed than that required

Field testing tractors in winter

when installed in the tractor. Due to the number of aliens working in the various plants, and the number of cases of sabotage, every case was sealed by Government inspectors as soon as the run was completed.

The 5-ton tractor motors were an evolution of the Class "B" truck motor, the tractor motor having modified cylinder blocks and overhead valves. The type motors were accepted for production after thoroughly testing them out against the Quartermaster "B" truck motor and various commercial motors of approximately the same horsepower. Motors were never a low point in the production of tractors, even with the rigid inspection given them. The motors were inspected on the assembling line in the same manner as the transmission, the first assembly inspection being the main bearings after they had been burnished in. This method



Inspecting tractor for oil leaks

of fitting the crankshaft to the bearings was proven early in production to be a better method than the conventional method of hand scraping. It also gave a much better bearing surface. It was interesting to note that of the 4,000 and more crankshafts made only five were lost, and they were rejected due to not having sufficient thickness of metal on the flange at the flywheel end.

The rest of the motor was inspected in accordance with commercial practice, and consisted of checking adjustments and preventing force fits where loose fits or running fits were called for. The complete motor was run in by belt for approximately four hours, then block tested with a calibrated fan for 12 to 15 hours, when the motor was cooled off and the cylinder heads removed for inspecting pistons, cylinders and valves. The oil pan was then removed and the bearing caps taken off and the oil grooves scraped out and inspected.

The motors were then reassembled and placed in the silent rooms for dynamometer test. They were allowed to idle for one-half hour prior to taking any readings. The test was then started and a complete log was kept of the performance of each and every motor. The average time required to test a motor in the dynamometer room was approximately two hours.

All other minor assemblies, such as track rollers, clutch assemblies and rear-sprocket assemblies, were given a rigid inspection prior to their being sent to the main-line assembly. This was done in order to guarantee proper assembly in the tractor and to reduce the main assembly inspection to a minimum. It required but one sub-inspector on the assembly floor, and his duties were principally to see that various components were not forced into place when an easy fit was called for. He also kept track of the serial numbers of the various components, and was responsible for giving the tractor its number.

The method of assembling in the case of the 5-ton tractors was to place the main frame on the line, after which the transmission was put in position, followed by the track-roller mechanism and then the track itself, right and left hand sides being worked on simultaneously. The placing of the driver's seat was next, and then followed the motor, radiator, Bendix hand starter and all minor attachments. Connections such as oil lines, gasoline lines and electrical wiring were then made. The motors were started at the end of the assembling line by means of a large electric starter, and the tractors driven to the field test-yard under their own power.

The average time to assemble a tractor on the main-line assembling floor was 50 minutes. This would have been reduced to approximately 20 minutes had hostilities not ceased, as the factory routing system had been studied, and it had just been decided to change various routings of material and lengthen the track so that more men could work on a tractor. The signing of the Armistice took a great deal of "pep" out of the workmen, with the result that production slacked off immediately.

In the test-yard shop, the tractors were given a thorough cleaning with super-saturated steam to clean them of all dirt and grease. This method also gave the metal sufficient temperature to enable it to dry more quickly than if washed by water. From the wash rack they were driven to the paint pits, where they were given a coat of olive-drab paint, and then driven to the test shed to dry, the motors still running. About one hour afterwards the tractor was dry and was on its way to the field for a try-out.

Tractors were under test in the field 24 hours a day. The estimated mileage, prior to any actual field test, was figured to be about 10 miles before a tractor would limber up and be ready for shipment, but this was soon proven to be insufficient, and up to the completion of the last tractor, few were ever accepted until they had travelled at least 20 miles. There were master-clutch adjustments, and readjustments of the steering clutches to be made after wearing-in of the clutch discs. A general easing up of all of the components

Equipping and camouflaging room

of the vehicle was also necessary. This increased mileage meant that about three times the number of field drivers and inspectors were necessary.

In order to relieve the labor situation, the Army Inspector of Ordnance authorized bulkheads to be built, and in front of these bulkheads a plate of sheet steel was placed. The tractors were driven on to this plate, the track oilers opened up and the tractors pintelled to the bulkhead. The tracks were then put in motion in low speed and the tracks allowed to slip on the steel plate. They were operated in

this manner to equal 5 road miles in each speed and reverse. Only one inspector was necessary to care for 6 tractors. By walking from one vehicle to the other he could observe the performance of each vehicle, make minor adjustments and also note excessive heating of the motor or any bearings. After the tractor had covered its mileage in a satisfactory manner, while held to the bulkheads, it was released to the field drivers for further test.

A towed load equivalent to their prescribed load of gun and caissons was then placed behind the tractors and they were driven over irregular terrain representing the worst conditions that a tractor would ever be subjected to. This test was absolutely necessary in order to make satisfactory carburetor adjustments, clutch adjustments, and to test out all castings under actual conditions. They were operated in marsh land in the summer time to load the tracks up to the limit with bog, sand, grit, etc., in order to locate defective track links, track tension springs and driving sprockets. In the winter time the same test was carried out in snow and ice at times when the temperature was far below zero.

Satisfactory running performance in the field was not alone sufficient to guarantee that the tractor was satisfactory. There were various individual tests to which it was subjected, such as test for oil leaks when the tractor was on a grade. In order to check this, the tractors were driven up a 60-degree incline and held there for 5 minutes, while the inspector examined the rear of the motor and transmission for leaks. The operation was then reversed and the front of the motor transmission were noted.

All bolts and nuts were tested for tightness, and inspected to see that cotter pins were in place. Fuel lines and all adjustments were checked, and then the tractor was ready for a final washing and second coat of olive-drab paint and delivery to the final acceptance room for shipment.

The armor (which was in one unit) and the standard ordnance tool box were put in place, and the tractor driven to the camouflage room. Here a process never before used was applied. Paint guns had been used for the two coats of olive-drab, but it did not stop at that point. One man marked off the camouflage design with chalk and marked each recess with the numbers 1, 2 or 3, number 1 being green, number 2 buff, and number 3 yellow. Each painter was given a number—1, 2 or 3. Number 1, using green paint, painted every place on the tractor that was marked 1, while number 2, using buff, filled in every place marked 2, and 3 proceeded in like manner. After the first few tractors had been run through in this manner, it was found that women could do this work as well as men, and women were hired, relieving the men for heavier work. The black striping was done by a man at the end of the paint line. The total time required for assembling armor, tool box and camouflaging was one hour.

Many times throughout the production of the 5-ton tractors there was a hold-up due to lack of track shoes and armor, which were the two low points throughout the war, but this did not hold up the production of the tractors. The tractors were camouflaged as far as they were completed, and the armor was camouflaged at a later date, when it was available. Many times after the tractors had been practically complete, they were driven into storage shops and the tracks removed, so that these tracks could be applied to vehicles on the main assembly line in order to drive them into the test yard. After camouflaging, the tractors were equipped with lanterns, pick mattocks, hatchets, etc., and driven aboard flat cars, when final inspection and acceptance was made, the tractor then being the property of the United States Government and on its way to its destination.

An Interview with General Williams

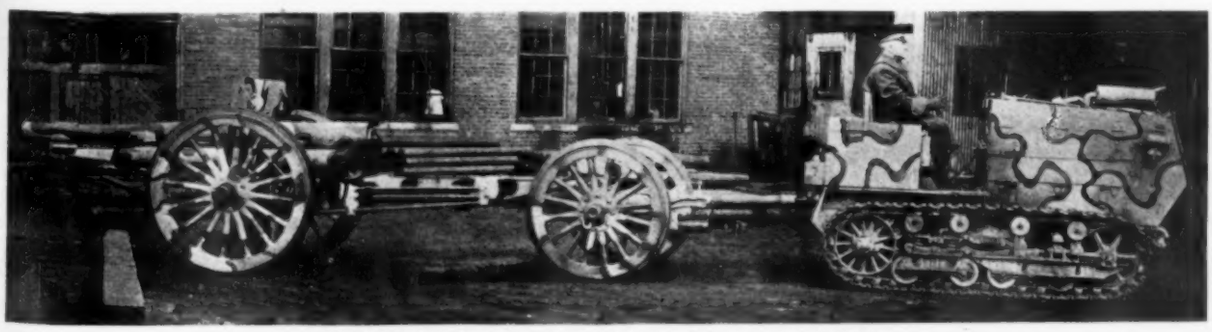
As a result of the developments during the World War things mechanical have taken on a new importance in warfare. Maj. Gen. Clarence C. Williams, Chief of Ordnance for the War Department, believes that the increased importance of mechanics in war has not been grasped by the public and is only partly realized by mechanics and mechanical engineers. If the country is to maintain its military position it must progress mechanically, he points out. As a consequence, he believes it to be an important step in the national interest that every mechanical engineer, every machine shop operator, and every mechanic should strive for higher standards and should always keep in mind improvements and developments in the vast machinery equipment of the modern army.

"In Cæsar's day," said General Williams in conversation with the *American Machinist's* Washington correspondent, "the civil engineer was the all-important adjunct to armies. Roads had to be built, bridges constructed and fortifications thrown up, but the mechanical equipment of the soldier of that period consisted of a short sword and a leather shield. Under conditions then existing the need for mechanical appliances was insignificant as compared with the need for civil engineering."

It was not General Williams' idea to minimize in any way the importance of civil engineering in modern warfare, but to contrast the growth in importance in the application of mechanics to warfare. He pointed out that the highest order of intelligence and the greatest of skill alone can cope with the myriad mechanical problems with which a modern army must deal. They range from the niceties of automatic pistol construction to the complicated systems of recoil on great guns. Every army mechanical problem, he declared, is further complicated by the fact that rough usage must be provided for.

The design, manufacture, operation and repair of the vast machinery equipment of an army is so great that it means that every soldier and every officer must be something of a mechanic, while a very considerable portion of them must class as experts. There must be specialists in literally thousands of lines. Military operations in the future will be on such a large scale that it will be utterly impossible for the little peace-time army to train more than a fraction of 1 per cent of the mechanics that would be needed were it necessary to enter a conflict with a powerful enemy. The army's specialists must receive their training in the nation's machine shops.

Incidentally, it may be said that General Williams is very much impressed with the success of American engineers and manufacturers in improving the military tractor. He will not be surprised if artillery traction is revolutionized as an outcome of that development.—*The American Machinist.*



The finished product—American made gun and tractor—Detroit, Mich.

Underlying Principles of Mechanical Combat Transport

By

W. F. BEASLEY

Member A. O. A.

IN considering the problem of mechanical combat transport, the question of *cross-country* transport, which may be utilized independently of roads, is of prime importance. For combat transport in the military service everything is subordinate to the ability to move irrespective of terrain or weather. In commercial service, ability to function in mining and logging operations, etc., where ordinary vehicles will not funtion, is essential, but reasonable concessions may be made to the weather and other local conditions.

While the track-laying or caterpillar type of vehicle in some form is at present regarded as essential for the cross-country work referred to, it is not the purpose of this article to advocate any particular type or to make any prediction as to what will be the ultimate type, but merely to point out the conditions which must be considered in any design in substantially the same way as the laws of water resistance must be considered by the designer of a ship, irrespective of what particular type of ship he may be building.

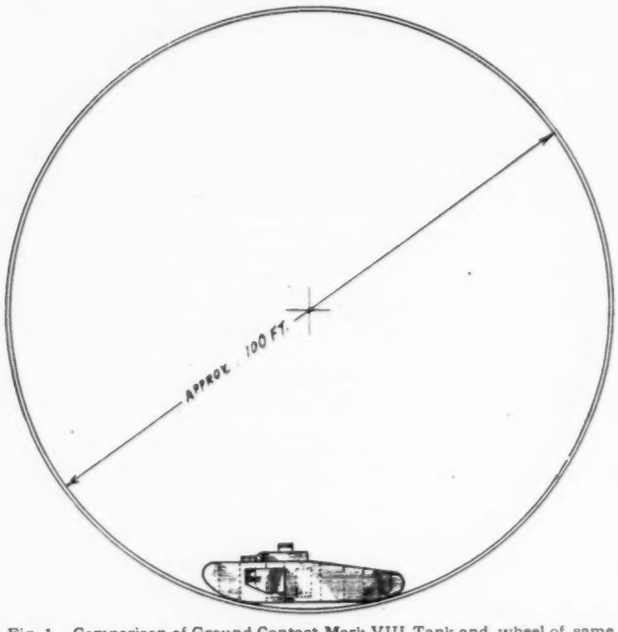


Fig. 1. Comparison of Ground Contact Mark VIII Tank and wheel of same obstacle surmounting ability

Ground Pressure. A first essential to crossing any ground that a man can cross is that the unit ground pressure should not exceed that of the unit ground pressure under a man's foot, or about 4 pounds per square inch. The first step in reducing ground pressure in a conventional wheeled vehicle is either to increase the diameter of the wheel or the width of tire, but practical limitations are very soon reached, as shown in Fig. 1.

What the track-laying vehicle really accomplishes is to substitute for the wheel a moving belt of comparatively small dimensions which has a surface in contact with the ground corresponding to a segment of a wheel of impracticable dimensions. Fig. 2 gives a general idea of the unit ground pressure under various classes of vehicles as compared with men and animals.

Even in the older types of vehicles there is no serious difficulty in bringing the unit ground pressure down to within 4 pounds per square inch, but in computing the unit pressure it has been customary to divide the total weight of the vehicle by the number of square inches of track surface in contact with the ground, and if the result showed a pressure of 4 or 5 pounds to the square inch, to pronounce the vehicle satisfactory. Such an answer may be entirely misleading, as the ideal is not an *average* ground pressure of 4 pounds per square inch, but a *uniform* ground pressure of 4 pounds per square inch, and the proper location of the center of gravity must be very carefully considered in connection with the question of ground pressure.

Fig. 3 shows a tractor moving up a 60-degree grade drawing a load, and shows that under the conditions assumed, the ground pressure at the rear end of the machine is much in excess of the average ground pressure, while the front end of the machine is practically lifted off the ground. This figure also shows that as the center of gravity is moved downwards, or to the front, the ideal condition of a uniform ground pressure is more nearly approached.

The center of gravity must, of course, be kept at a considerable distance above the ground in order to provide a proper clearance under the vehicle, and if the center of gravity could be moved forward indefinitely there would be danger of overturning to the front when descending a steep grade. In descending a grade the towed load must be braked in any event, and considering the vehicle alone, as shown in Fig. 4, the center of gravity may be moved well forward without greatly increasing the chance of overturning to the front.

Practically, it has been found that if the designer makes every effort to move the center of gravity as far to the front as possible in a vehicle intended to pull other loads, and keeps it as near the center as possible in the case of a tank or cargo carrier, the maximum ground pressure under the track will be kept within reasonable limits under extreme conditions, and the maximum degree of stability will be obtained. Photographs of the newer tractors make these vehicles appear awkward when standing alone on account of the nosing downward, but as soon as a draw-bar load is applied the vehicles ride on a even keel.

Clearance and Center of Gravity. As these vehicles are required to move both up and down the steepest grades and to turn thereon, the center of gravity must be kept as low as possible consistent with the proper clearance under the vehicle, with a view to minimizing the danger of overturning. The effect of the location of the center of gravity on ground pressure is discussed in detail under the heading of "Ground Pressure." The overall width of the vehicle and

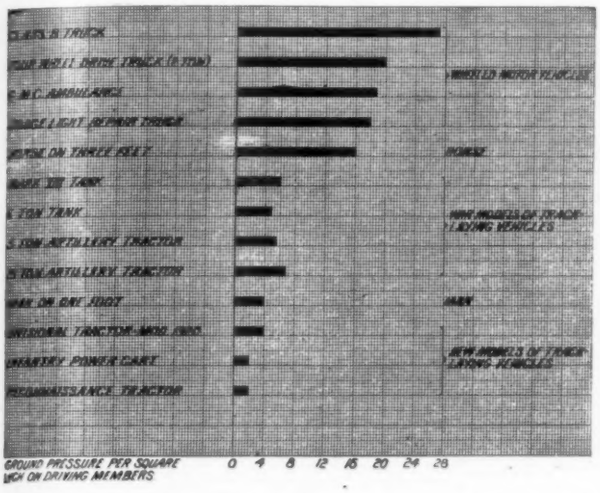

WHEELED MOTOR VEHICLES
POWER
ARE WHEELS OR TRACK LAYING VEHICLES
ARE WHEELS OR TRACK LAYING VEHICLES
GROUND PRESSURE PER SQUARE INCH ON DRIVING MEMBERS
0 4 8 12 16 20 24 28

Fig. 2. Comparison of Unit Ground Pressure under various vehicles, men and horses

the distance between tracks is further limited by the fact that a large majority of these vehicles must track with other vehicles, such as gun carriages, but in most cases sufficient overall width is permissible to make the vehicles quite stable against overturning sidewise, providing the center of gravity is kept reasonably low.

Actual experience has shown that in this type of vehicle a vertical clearance of about 12 inches under an average-size vehicle is sufficient, provided any parts, such as engine crank cases, liable to injury from stones or stumps, are protected by suitable guards. In addition to the vertical clearance underneath the body, it is equally essential that the tracks extend a sufficient distance in front and to the rear of the body proper so that there is little danger of the body being hung up on the edge of a ditch or some similar obstacle before the tracks have taken a sufficient hold to surmount the obstacle.

Transportation. When loaded on standard American cars without special care in centering the vehicle on the car, the vehicle must clear all obstructions on standard gauge and, if practicable, on narrow-gauge American railways. In case of large and important vehicles, study must also be given to the possibilities of transport on foreign railways using the railway rolling stock peculiar to the country. Railway clearance diagrams should be studied in case of doubt.

Suitable hooks or rings permanently fastened to the vehicle should be provided to permit loading with cranes without damage to the vehicle proper or any boxing that may be provided over the engine or other parts to prevent damage in overseas transit.

Gear Reductions. The gross tractive effort of the vehicle is, of course, dependent on the grip of the track of the vehicle on the ground. Experience has shown that the maximum adhesion on the ground is obtained when the power is applied slowly, as a rapid application of what would otherwise be ample power frequently results in the track tearing away the surface of the ground, and if continued long enough digs the vehicle into the ground with resulting stalling.

Practical experience has shown that in order to develop the maximum tractive effort it must be possible to apply the maximum torque of the engine to the track with a gear reduction giving a vehicle speed not exceeding one mile per hour. When the vehicle is running at the maximum speed desired, say 16 miles per hour, the maximum torque is again necessary to overcome the various resistances due to high speed. The net result is a requirement that the maximum torque of the engine be available at speeds from one mile per hour to the maximum speed desired.

Well-designed engines of conventional design, at some point of their speed range, maintain a constant torque while the speed doubles; for example, from 700 r. p. m. to 1,400 r. p. m., or from 800 r. p. m. to 1,600 r. p. m. If a maximum speed of 16 m. p. h. is desired, it is therefore necessary to provide a speed range of about 1 to 8 in the transmission system regardless of the particular type of system which may be used. As an example of the practical working out of this problem, one of the vehicles now under design, which uses an engine with approximately constant torque from 800 r. p. m. to 1,600 r. p. m. and a conventional three-speed transmission, on which is superimposed a two-speed transmission, has the following speeds, which makes maximum engine torque available in any transmission speed.

Engine speeds, r. p. m.	800	1,200	1,600
Vehicle speeds, m. p. h., low range	.85	1.28	1.71
	1.47	2.21	2.95
	2.7	4.1	5.5
Vehicle speeds, m. p. h., high range	3.4	5.1	6.8
	5.91	8.86	11.82
	10.7	16.1	21.4

Controls. Track-laying vehicles are steered by the relative movement of the tracks with each other and, as has been previously explained, it is essential that the maximum drawbar pull be delivered to the tracks at very low speed. There is considerable divergence of opinion as to the best method of controlling the operation of the two tracks, and an excellent presentation of this subject is contained in the ar-

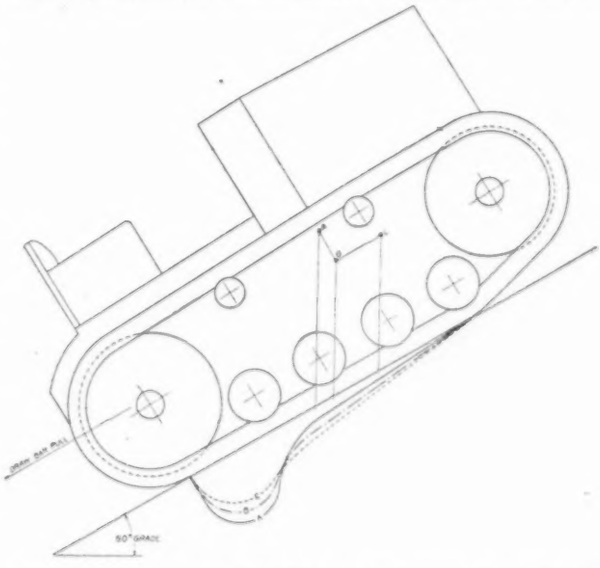


Fig. 3. Effect of location of center of gravity on ground pressure, vehicle ascending grade

ticle on "Final Drive for Combat Vehicles," in this issue, by G. R. Pennington and S. K. Wellman.

In addition to the methods discussed in the article referred to, some of the larger tanks carry the final drive to each

track through a planetary system on each side. By means of setting the proper brakes this method permits either side to be put in high, low or neutral, and in a few experimental English tanks three, or even four, speed planetaries, or epicyclics, have been used on either side. On account of their weight and complication, it is not likely that such systems will ever be used except on extremely heavy vehicles, such as the larger tanks, in which the shifting of gears is considered impracticable.

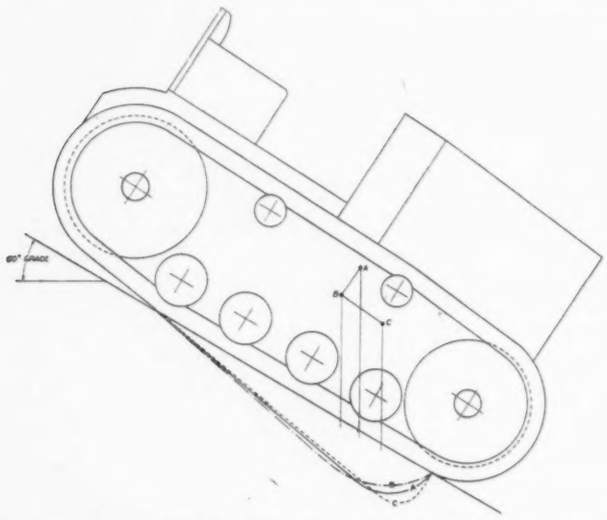


Fig. 4. Effect of location of center of gravity on ground pressure, vehicle descending grade

Power Plant. The power plant should be of the conventional heavy-duty type running at comparatively low speeds and capable of operation under full load for extended periods. The fuel and oil supply should function properly when the vehicle is on maximum grades and when tipped sidewise at extreme angles. All parts requiring adjustment or replacement should be accessible in order that adjustments and replacements can be made with the minimum loss of time.

Experience has shown that approximately 15 brake horsepower per ton of vehicle weight is required to meet high-speed requirements, and that the engine torque and gear reduction should be such that the draw-bar pull at 1 mile per hour will at least equal the weight of the vehicle.

Radiator and Fan. The cooling system for military vehicles should be superior to that required for commercial vehicles of like draw-bar capacity, and should have sufficient cooling capacity to enable the vehicles to operate continuously for 24 hours under temperature conditions encountered in tropical countries when pulling their rated draw-bar loads.

In the case of vehicles required to operate under fire, necessitating armor protection for vital parts of the vehicle, the vehicles should be capable of 5 hours continuous operation, with all armor openings closed, over the most difficult terrain encountered under combat conditions, without failure of the cooling system.

The fan should be of ample size and properly housed to satisfy the conditions laid down above. The fan drive should be through a clutch or similar device to protect the fan and belt against the accelerating or decelerating forces incident to sudden starting of the engine or passing through water.

Waterproofing. Men or animals can cross water approximately 5 feet deep without serious difficulty, and, by swimming, a limited number of individuals can cross greater depths, while the average motor vehicle is stalled in from 2 to 3 feet of water.

As long as motor vehicles were only employed with the heavier types of artillery, which would ordinarily find a bridge or which time would permit to pull over piece by piece, the waterproofing of the ordinary vehicle was reasonably acceptable. Combat vehicles, such as tanks, divisional artillery tractors and machine-gun carriers, which are expected to move with or follow close behind the first lines of infantry, must, however, cross water with no greater hesitancy than infantry or horsed "75's." It is therefore essential that all motor vehicles for combat service be able to cross water at least 5 feet deep without difficulty. The waterproofing arrangements must be as simple as possible, and preliminary experiments have shown that this requirement is entirely reasonable and can be met with comparatively slight modifications of existing material, reference being made for example to the waterproofing of the carburetor, shown in Fig. 5.

Tracks. Assuming a uniform co-efficient of friction between the ground and the tracks and uniform load distribution, a track-laying vehicle theoretically will not steer when the length of track in contact with the ground becomes twice the distance from center to center of tracks. This condition is illustrated by Fig. 6, and in actual practice it is customary not to have the length of track in contact with the ground exceed approximately 1½ times the distance from center to center of tracks.

It is further apparent from Fig. 7 that the conventional track made up of steel links and pins should be driven by a sprocket not in contact with the ground, otherwise the rear axle will be raised as the sprocket crosses each link with corresponding vibration and loss of power. In addition to the above, the angle formed between the ground and front and rear parts of the track, commonly known as the angle of approach and departure, is helpful in surmounting obstacles, entering and leaving ditches, shell holes, etc.

As a normal condition it must be expected that dirt, stones, etc., will pile up on the part of the track lying on the ground. No track mechanism can be successful that does not take care of such obstructions without introducing undue stresses into the track mechanism. Fig. 8 shows what is required and demonstrates one successful method of taking care of obstructions.

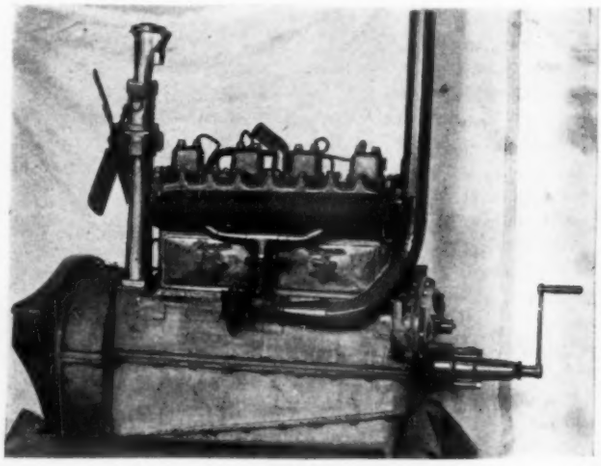


Fig. 5. Waterproofed Motor, carburetor side

In addition to a positive means of cleaning the track as a whole, it is desirable that obstructing material, such as

earth, gravel, etc., which is divided into small particles, be expelled through the sides of the track links, or otherwise, by the pressure of the teeth of the driving sprocket, instead of permitting a mass of obstructing material to accumulate between the driving sprocket and track.

The track should be of a design that adapts itself readily to irregularities of the ground the vehicle is required to

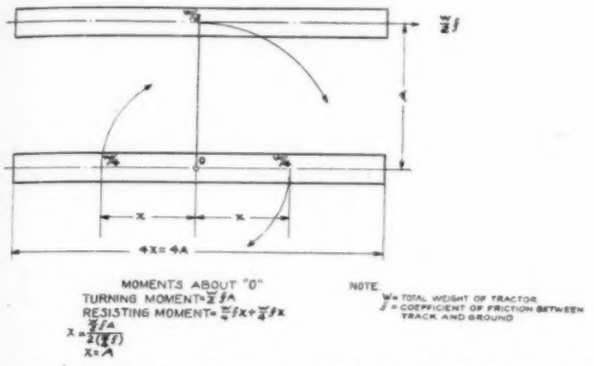


Fig. 6. Maximum length of ground contact in Track-laying Self-propelled Vehicles

negotiate, and should enable the vehicle to cross such irregularities without undue pitching or shock. The track mechanism should run smoothly, and the spring or cushioning system should be so arranged that the unsprung weight will be a minimum. The track proper should be as light as possible, as experiments have shown very high power losses in heavy tracks moving at high speed, with correspondingly destructive effects on the tracks and adjacent mechanism.

In vehicles required to operate at high speed, rubber or other shock absorbing material may be used on sprockets, track rollers and idlers, but care should be taken in the application of such materials, that they are so applied that the emergency operation of the vehicle will not be prevented in case of failure of the shock absorbing material. In this connection the present tendency is to introduce rubber as near the ground as possible, and to introduce springs as soon as practicable above the rubber, which closely parallels standard truck practice.

Means of adjusting the track to compensate for wear should be provided, and vehicles using the conventional track made up of links and pins should be provided with a track-oiling system of sufficient capacity for at least a day's run. This system should include a valve or other means of shutting off the oil supply when the vehicle is not in operation.

Grousers and Treads. In order to develop the maximum draw-bar pull of the vehicles, it is essential that a most effective grouser system be used, as in all satisfactory vehicles the theoretical draw-bar pull is equal to the weight of the vehicle and the actual draw-bar pull developed is entirely dependent upon the efficiency with which the vehicle grips the ground. However, when a track-laying vehicle is steered, the tracks slide sidewise on the ground and the grousers are liable to tear up the ground or spoil good roads. It must therefore be possible to present a smooth surface to good roads which will not injure the surface, but this, in turn, presents difficulties when operating on ice or snow.

The track shoes of most of the present vehicles have a smooth surface, which will not injure good roads, and for use off the roads depend on the application of a large number of detachable grousers, which take considerable time to apply and which are subject to loss. This system is peculiarly objectionable when passing successive stretches of bad roads or when turning off the roads from time to time to pass obstructions, as there is not time to put on or take off the grousers as conditions change.

What seems to be the best solution with the present conventional tracks of steel links appears to be to form each link so that its center will present a smooth surface to the ground, but with large depressions on each side of the center which act automatically as grousers as soon as the vehicle sinks slightly into soft ground. Preliminary tests of this type of track indicate that the system will be successful

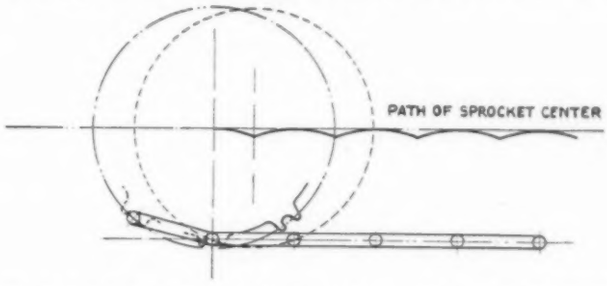


Fig. 7. Result of permitting driving sprocket to come in contact with ground

for all ordinary conditions. For extreme conditions, for operation on ice, etc., it may be necessary to provide in the equipment a few special grousers for occasional use, but this is not particularly objectionable.

Gasoline Feed. Is should be possible to feed the last fuel in an almost empty tank to the carburetor, and the carburetor must function when the vehicle ascends or descends a 100 per cent grade or is tipped to either side on approximately an 80 per cent grade. Actual experience has shown that at least 50 per cent of the stoppages are due to breakage or stoppages in the fuel system, and it is of prime importance that the piping and connections be kept at a minimum. Neglect of the simplest parts of the fuel system has caused designers far more trouble than other points which they considered of more importance.

The carburetors must, of course, function at extreme angles, and the carburetor and gasoline piping must be so arranged that there is no chance of gasoline dripping on the magneto, exhaust manifold or other places liable to cause fire. A large sump that can be drained directly to the ground should be provided on the gasoline tank and the

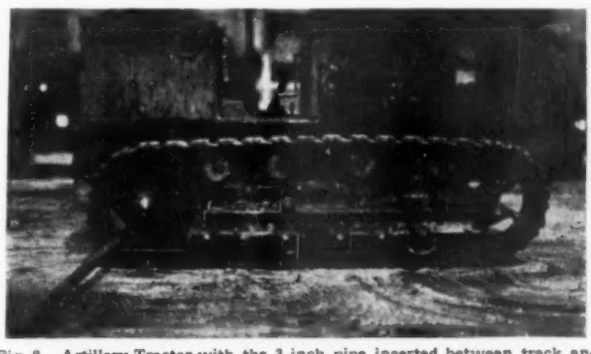


Fig. 8. Artillery Tractor with the 3-inch pipe inserted between track and sprocket to show clearing ability of this type of track

tank itself must not leak at extreme angles or permit the entrance of water when the vehicle is submerged to the depth the particular vehicle is designed to negotiate.

A reserve tank, preferably contained within the main tank, which will feed directly to the carburetor by gravity, is desirable, but does not justify undue complication in the gasoline system. All parts of the gasoline line must be se-

curely fastened to minimize the effect of vibration. In actual practice, trouble of one form or another has been experienced with every known type of feed, and the only conclusion that may be reached is to reiterate that the gasoline system should be the simplest possible consistent with other requirements and should receive most careful attention on the part of the designer.

Oiling. In any heavy-duty vehicle, and particularly in the type of vehicle under discussion, the lubrication system is of primary importance and should function properly with the vehicle standing on any grade which it is capable of negotiating or tipped sidewise to the maximum angle at which it is stable, and no leakage should occur if it is left standing at such an angle.

Inclosed cases containing lubricants should be provided with breathers open to the atmosphere at sufficient height above the ground to prevent the entrance of water when the vehicle is submerged to the depth its waterproofing is designed to negotiate. Where shafts enter or leave, cases containing lubricants, stuffing boxes or other suitable means should be provided to prevent the entrance of water.

Any packing between rotating and stationary parts should be of the smallest diameter possible to minimize the entrance of dirt and water and resultant wear, adjustment or replacement.

Distortion and Vibration. In vehicles required to operate off roads and over the roughest kind of ground, provision should be made to protect the independent units entering into the design from injurious stresses resulting from frame distortion. In general, three-point suspension and some form of flexible joint between units or equivalent construction should be employed. Parts liable to damage from vibration should be protected by the use of springs, leather pads, or other methods as required by the particular case under consideration.

Starting and Ignition. On all vehicles capable of being hand-started, the ignition system should consist of a high-tension magneto equipped with an impulse attachment.

On vehicles of larger sizes, some source of power, such as a motorcycle engine, should be provided to operate the starting mechanism.

The magneto should be designed to give the minimum spark lag at all engine speeds. The range of spark advance should be 30° of crank angle or over, and should be controlled from the driver's seat.

Some of the larger vehicles may be provided with electrical starting apparatus, but with such vehicles it is required that it be possible to start them with the batteries removed simulating the failure of a battery in the field.

Muffler. The muffler is a simple accessory which in actual practice gives a great deal of trouble. The muffler as such, should be as effective as that on a good touring car, as noise under certain conditions is not permissible. The disposition of the exhaust gases is also of importance, as in a close convoy, or even on a single vehicle, if the muffler is badly located the crew may be seriously affected by the exhaust. At present the only disposition of the gases that appears reasonably satisfactory is to blow them vertically into the air, the point of discharge being above the heads of any of the crew. This seems to dissipate the gases sufficiently so that there are no ill effects, and danger from blowing up a cloud of dust or setting fire to dry grass is avoided. Care must, however, be taken that the muffler in this position does not emit flame, which would expose the vehicles to aerial observation at night.

Anti-Aircraft Gunnery

By

R. L. GOETZENBERGER

Member A. O. A.

THE airplane as a vital issue of invasion in time of hostilities became a factor of such magnitude during the recent war that every possible means of defense against it were applied. Anti-aircraft artillery gave most commendable results in this regard.

The science of anti-aircraft gunnery originated with the World War. In no other branch of artillery application were more rapid advances made in the solution of the problems involved and the development of automatic apparatus to control the firing of its guns. It has been the attempt of the author of this article to present in a general manner a popular conception of the principal factors of this new artillery science.

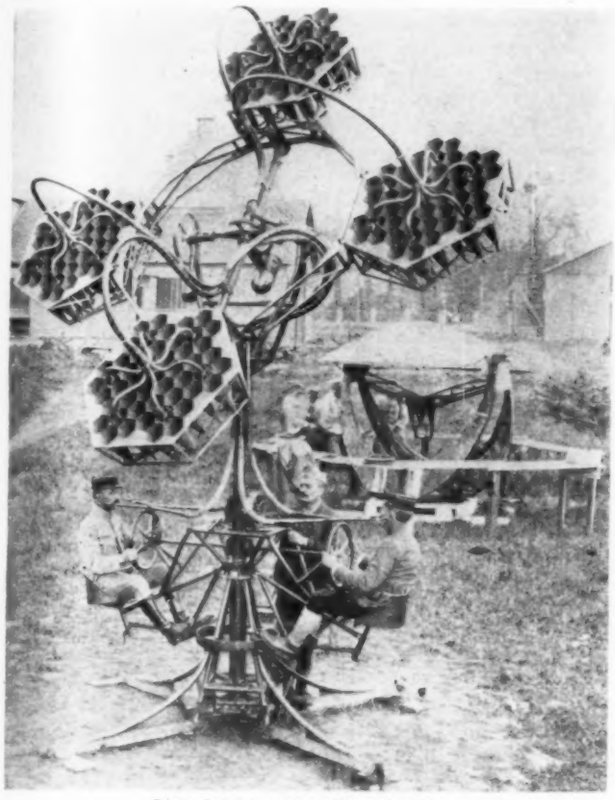
The effectiveness of the anti-aircraft artillery service in France has been shown by relating statistics. A description of the defenses of the region of Paris illustrates the scope to which the service was developed during the period of the war, and introduces an appreciation of the future possibilities of similar defenses in this country.

Anti-aircraft Artillery

In many respects anti-aircraft gunnery bears similarities to game-bird shooting. From the observed or present position of the bird a lead is given to the gun in order to compensate for the movement of the target during the time required in loading, aiming and firing the weapon. Speed of the target, its distance away from the gunner and windage determine the lead, in other words, angular displacement, to be given to the gun. A good eye with the shotgun is as important as an accurate laying of the sighting system of an artillery caliber weapon. Alertness of aim and rapidity of firing are likewise comparable.

Let us now examine some of the principal differences between the two forms of bird shooting. The shotgun uses a shell comprising a number of shot, which disperse immediately upon discharge from the barrel. The artillery weapon fires a projectile, the instant of bursting of which is governed by the burning of the powder train or functioning of a clockwise mechanism of the respective types of fuses that had previously been set to the predetermined range. While it is the purpose of every artilleryman to kill his bird, nevertheless he also realizes that if his shot bursts close enough to the aviator, the ripping noise of the high-explosive shell will so disturb the morale of the pilot that

he will fear continuing his course, and therefore turn back without completing the mission for which he set out. In anti-aircraft gunnery every round fired is a measured round



Listening Apparatus of French design

rather than a series of pot shots common to game hunting. Greater ranges that involve, of course, longer intervals of time in the determination of lead, and a target which is prone to exercise its brains to outwit the gunner, each add to those factors which cause difficulty in the determination of gun displacements.

Like a game bird which flys from one place to another for the purpose of seeking food, its nest, or migrating, an aviator generally directs his airplane for the distinct purpose of accomplishing his mission in the shortest interval of time. Consequently, the straightest course is chosen by both. To take on altitude means an expenditure of energy and loss of time. Therefore the airplane attempts to fly at constant altitude. At a definite speed the engine of an airplane functions with the highest efficiency. This velocity, varying somewhat with the altitude, can safely be assumed to remain constant for each height. Consequently we arrive at our working hypothesis for all data calculation in anti-aircraft gunnery—namely, rectilinear motion, which assumes that the target will fly a straight course at unchanging engine speed and at constant altitude during the time required in the determination of the gun deflection data, fuse setting, firing, and, in flight, for the projectile to reach its point of burst.

Our hypothesis has proven from practice to be a reasonable one. Had we calculated on three dimensional movements, the probability of hitting an airplane of average speed characteristics with a projectile of 3-inch caliber would have been one in two million rounds. The assumption of rectilinear travel reduces this probability factor to one in one thousand rounds. Our actual firing records show seventeen airplanes brought down in 10,275 rounds fired by us along the front lines during the war. Therefore the proportion of one airplane brought down in 605 rounds of ammunition proves that rectilinear travel holds an important place amongst all possible motions, and that firing by calculation is highly preferable to fire by chance. But the measure of the efficiency of anti-aircraft artillery should not be confined solely to the basis of number of airplanes actually shot down. Its efficacy should also be evaluated against the protection it gives in forcing enemy aviators to turn back without accomplishing the missions, such as reconnaissance, artillery regulation, bomb dropping, etc., for which they set out. This it does with remarkable effectiveness. Many cases of aviators shell-shocked by anti-aircraft projectiles were recorded during the war.

Anti-aircraft gunnery in general falls under two separate and almost distinctly different subdivisions—day and night firing. During the day the airplane is seen and at night heard. Consequently, optical instruments are employed in the former and acoustic devices in the latter case. We will treat with principles and equipment for day operations first.

Day Operations of Anti-aircraft Artillery

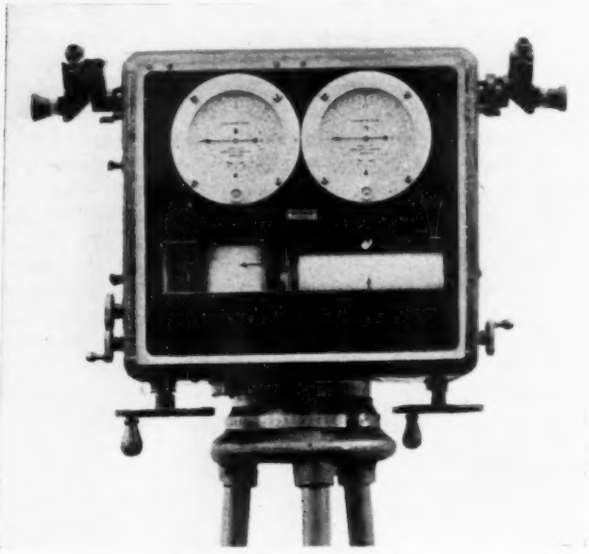
Direct observation upon the target by the telescopes of the fire-control instruments establishes the present conditions—namely, azimuth, angle of sight, altitude and range. By following the target in azimuth and elevation, simultaneously driving through the mechanism of the first-control instrument either a mechanical or electrical device for measuring its angular velocity, then automatically multiplying within the instrument this velocity by the computed time of flight for the travel of the projectile to the predicted future position of the target, both the lateral and vertical angular displacements or settings for laying the gun to the target's predicted future position are obtained.

Two types of instrument were used during the war to accomplish this measurement. The corrector Brocq with range indicator is an electrical device which not only resolves angular displacements, but also, by virtue of the range-indicator element, a double coil voltmeter, provides the means for obtaining fuse range in function of the angle of sight to the predicted future position of the target

Corrector Brocq with Fuse Indicator, illustrating double sight, fuse indicator, gun voltmeters, cable, storage battery and terminal board elements

and the altitude. The corrector R. A. determines similar data mechanically. It contains ordinary speedometers driven from rollers which move radially across friction

dises proportionally to the time of flight, thus recording directly the lateral and vertical displacements of the target. Fuse range is also determined by this instrument. The



Corrector R. A., Type U. S. A.

data obtained at the fire-control station is telephoned to the gun emplacements.

The altitude of the target is an important element in the resolution of fire-control data. It is determined in one of two ways, either monostatic or bistatic. By monostatic we refer to a single station instrument of the coincidence, self-contained range-finder type with an attachment that logarithmically deduces altitude from the measurement of the geometric distance to the target and the angle of sight. Both mechanically and electrically operated attachments have been applied. This type of device has several objections that limit its use. It is difficult to hold coincidence when viewing a target moving as rapidly as an airplane. The stereoscopic principle appears to have some decided advantages over coincidence, but as yet has not been successfully constructed. Unless its length be longer than two yards, which seems to be the logical limit for field portability, the errors often become very appreciable except when being manœuvred by the most skillful operators.

Bistatic altimetry refers to a two-station principle. The altitude is found by using a horizontal base of known length and projecting the altitude into the vertical plane through the base line. Since each base-end instrument observes the target simultaneously, the roof angles are continuously read and the distant-station one is set at the fire-control central station upon the conjugate altimeter there. The known base length and the two angles give an immediate resolution of the altitude. The Altimeter, Model 1917, is an example of the latest type of instrument. For low-flying airplanes, the projection is into the horizontal instead of the vertical plane containing the base line. Bistatic altimetry has the objection that it is difficult to so specify a particular airplane which might be one of a flight, that both stations, frequently three thousand or more yards apart, will simultaneously view the same target. Telephony is relied upon as the means of communication between stations.

In event of failure of the corrector Brocq or R. A., both instruments being based upon the angular travel method, another system of fire control has been used. This bears the name Linear Speed Method, because it involves the linear motion of the target. It was employed by our artillery as an emergency means of control. The success of its application depends upon the skillfulness of the personnel of the fire-control station in estimating data and operating the deflection computer. The element, speed of the airplane, can be estimated with fair accuracy if one can always distinguish the make of airplane and is familiar with the characteristics of that model. However, the estimation of the angle of presentation, which is the horizontal projection of the angle between the line of sight and the line drawn through the fuselage of the target, admits of considerable error. The linear speed method is made considerably more inaccurate in that it requires an exact determination of the velocity of the wind at the altitude at which the airplane is flying.

The speed computer is the instrument used in measuring either the speed of the airplane or the wind velocities at different altitudes when meteorological station data is unavailable. The latter procedure is accomplished by observing the smoke of a burst of a projectile fired to a known altitude, preferably the maximum ordinate of the trajectories.

In the case of the linear speed method, fuse range is obtained from a range computer either attached to or separate from the gun carriage. In both instances, fuse range is a function of the altitude and the angle of sight to the predicted future position of the target. It is read from a graph of curves of constant fuse range, the slopes of which change at different points because of the exterior ballistic variations in high-angle firing. Together with the displacement data resolved on the deflection computer, fuse range is sent to the gun emplacements, where it is used in effecting the fuse setting and as a function in giving the gun the angle of super-elevation—namely, the angle between the line to the predicted future position of the target and the line of elevation of the gun at the instant of firing.

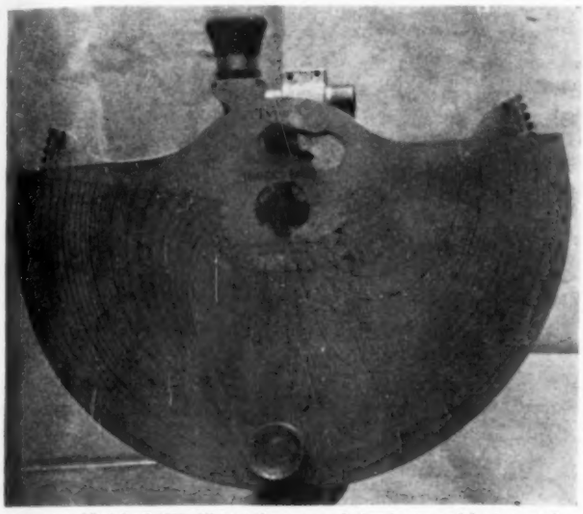
Night Operations of Anti-aircraft Artillery

Night firing substitutes for the bistatic altimetry stations acoustic centers where skillfully operated listening apparatus of the trumpet or paraboloid type gives azimuthal and elevational data by focussing the sound of the airplane engine. This data is transmitted to the fire control room, where it is used in plotting the course of the raider, obtaining its altitude, plotting the course, thence resolving the

Two-Meter Base Range and Height Finder of the Monostatic Type

azimuth, elevation and fuse range to the predicted future position of the target. This final data is sent to the gun emplacements, where it is used in setting the pieces. This

sub-division of anti-aircraft gunnery is indirect firing and, accordingly, involves corrections for parallax—namely, those secondary deflections required because of the non-



Altimeter, Model of 1917, illustrating one of the base end instruments for bistatic altimetry

coincidence of the fire-control station with the gun emplacements and obtained in a manner identical to the principle for indirect fire during the day. These corrections are computed upon a parallax dial either made a part of a composite instrument known as a battery commander's telescope with wind and parallax dials or placed upon the guns, which gives a very satisfactory solution, assuring the resolution of these corrections directly at the guns, a vital issue when the guns of a battery are widely separated and at some appreciable distance from the fire-control station.

Anti-aircraft Defense of Paris

Perhaps no cities, including their outer regions, were so well protected by anti-aircraft defenses as Paris. A few statistics will be given subsequently to illustrate the importance played by those defenses of Paris in resisting incursions of hostile airplanes. First, however, let us treat with the organization of the defense and the methods employed in the control of barrages. In order to distinguish the term barrage as applied to terrestrial from that referred to as celestial firing, a curtain of fire is meant in the former case and a volley of four or six rounds with the same gun and fuse settings in the latter.

The command of all units of the Paris defense was centered in that city, in fact, in one large room. Against a wall of this room was a map showing the location of all elements of the defense, which, as will be explained, enabled one to follow the route of enemy airplanes and all phases of combat. An ingenious arrangement of direct telephone communication with the defense elements, and an automatic system of signal lights permitted the progress of the raiding party to be continuously indicated on the map immediately upon its crossing the lines at the front. One officer had supreme command over all outlying defenses and, observing the map notations, would order those batteries in the path of the raider to open fire at the proper moment. Direct communication by telephone to battery locations, listening posts, etc., not only in the neighborhood of Paris, but also extending to the front, permitted immediate control over all elements of the wide defense.

In order to keep the command in Paris thoroughly informed of the movement of aircraft, friendly or enemy, a permanent observation service was at all times maintained. An extensive system of special sentry posts was established throughout the region. Other posts, equipped with listening apparatus, would determine the approximate altitude and route of raiders even before they came into range of the first line of anti-aircraft batteries. The telephone liaison necessary between these posts and those booths around the headquarters room of the supreme command in Paris, constituted an extremely complex system involving more than four thousand miles of aerial and subterranean lines.

The means of defense employed are classified under two general headings:

1. Passive,
2. Active.

Passive means consisted either in placing obstacles, such as captive kite balloons, along the most likely routes followed by the raider or of misleading him by means of camouflage of the terrain—for example, smoke masking, building false scenery, and placing a confusing disposition of lights.

The active means comprised a methodical and continuous combat against the raider. It involved the employment of aviation, anti-aircraft artillery, searchlights and machine guns.

The employment at night of aircraft to combat aircraft is more difficult of application than most persons are prone to believe. It is difficult for aviators to see clearly enough at night to distinguish friendly from enemy airplanes, even with the best of conditions for visibility. This form of combat was, however, used to some extent by the British in defending London by sending up aviators from coast stations to fight raiders during their flight across the English

Trumpets of British Type employed as listening apparatus for fire control of Anti-Aircraft Artillery at night

Channel. Control of their movements was effected by wireless telephony from a central station command. On account of the danger involved to friendly airplanes, they should

never be employed in zones to be defended by anti-aircraft artillery, because listening apparatus from which data for laying of the guns of the batteries are derived can not distinguish between the noise of friendly and hostile airplanes.

Large bombing airplanes, heavily laden not only with bombs, but also with a large quantity of gasoline and oil, can not attain great heights, and therefore generally fly at about three thousand yards altitude. At this height the anti-aircraft artillery has a large field of fire, and the firing of many batteries will always intersect and can be concentrated simultaneously on the same target. At night the aviator always fears becoming lost, because they are forced to fly by compass, using the terrain only to verify their route. Therefore, they fly a straight course pointing directly at the objective so long as they are not obliged to dodge. At night the sound of motors is heard much better than by day. Thus, sound ranging is conducted under much more favorable conditions, in fact, an airplane heard at a long distance can be located and its altitude determined before it comes within the field of fire of the battery. These are the principal conditions differing from day flying, when greater speeds, higher altitudes, and, occasionally, poor visibility, due to dazzling light, are prevalent.

U. S. 3" A. A. Gun Mount, Model 1920, illustrating the mount minus the four-wheeled trailer element

It has often been asked why it is that the artillery fires by sound at night, when powerful searchlights, by making the airplanes visible, should permit "direct" firing. But the illumination of an airplane by searchlights is a difficult problem, it being based, like artillery fire control, on the exact location by sound of the successive positions of the target in space.

The sound of the motor is not instantly heard. It travels through space scarcely ten times as rapidly as the airplane. The result is that an airplane located at a certain point has moved some distance from that point when the sound emitted is heard. Therefore, it is necessary to predict the future position and to illuminate it, sweeping a zone in prolongation of its route.

Searchlights have for their main mission the blinding of hostile aviators, preventing them from seeing their guiding points on the earth; to compel them to change their course in order to escape the confusion caused by the luminous beam; to assist friendly aviators in designating and attacking raiders over zones not defended by artillery.

Any anti-aircraft mount designed for day firing is likewise suitable for night barrage service, if it incorporates all devices required for "indirect" laying. Unlike day firing, when each round fired is a measured one, night firing is conducted by salvos of about six rounds without altering the gun and fuse settings.

One needs only to refer to the results obtained by the Paris defenses to appreciate the valuable service rendered by anti-aircraft artillery against night bombing raids. Records show that of the 483 airplanes sent by the Germans during 1918 toward Paris for the purpose of bombardment, only 31 of this number succeeded in flying over Paris, and 13 of these were brought down by the defenses. This is an excellent record for the anti-aircraft defenses considering the size of mark Paris offered. Recalling the enviable record made by our batteries along the front in day operations and combining with it that just mentioned, our problems enter their second or future stage—the improvement of the present methods of gunnery and perfection of material.

In the foregoing paragraphs an attempt has been made to describe briefly fire-control methods, instruments and applications for both day and night service of anti-aircraft artillery. Having derived the data at the fire-control station, we will now transfer our attention to the equipment of the gun emplacements, upon which this data is applied in setting the gun deflections and fuse of the projectile.

Anti-aircraft Mounts

Anti-aircraft mounts are divided into two main classifications—fixed and mobile. A mount is fixed when it is permanently placed in a location to defend a definite area. An example of this classification is the U. S. 3-inch A. A. Gun, Model of 1917, mounted on A. A. Mount, Model of 1917 (Barbette), which is designed to be attached to a solid concrete base. Under the latter classification falls the U. S. 3-inch A. A. Gun, Model of 1918, mounted on auto-trailer, Model of 1917, and 75-mm. Gun, Model of 1916, mounted on A. A. Truck, Model of 1917. Both of these carriages can be readily moved from place to place and put into battery quickly by merely jacking the weight off the chassis springs. No mounts of U. S. design were available for our use in France, but are now on hand in considerable quantity in this country and are being assigned to coast artillery stations for instruction and drill purposes. Our anti-aircraft service operated French carriages—namely, their semi-fixed truck and trailer mounts, each equipped with the standard 75-mm. field gun.

After a comprehensive study of all kinds of carriages used during the war, it has been concluded that but two types are necessary. The ideal of each type is described as follows:

Light Gun. 3-inch, with initial velocity not less than 2,600 foot-seconds, semi-automatic breech block, mounted on a

carriage permitting 80° elevation and 360° traverse; projectile weighing not less than 15 pounds, one type H. E. shell with maximum ballistic qualities and as large bursting charge as practicable; fixed ammunition; mechanical fuse.

Mount. Self-propelled caterpillar or caterpillar trailer drawn by caterpillar tractor, each unit to permit of sustained speed of 12 miles per hour.

Heavy Gun. 4.7-inch to 5-inch, firing projectile weighing not less than 45 pounds. Gun to satisfy same requirements as specified above for light gun.

Mount. Self-propelled caterpillar, permitting a sustained speed of 8 miles per hour, maximum weight not to exceed 10 tons; trailers to be provided for long hauls.

Added to these specifications our development of anti-aircraft ordnance must be made to satisfy as nearly as possible the following general requirements:

1. Minimum time of flight of the projectile.
2. Increase in volume of effective explosion (shell power).
3. Rapid rate of fire.

With an appreciation of these requirements in mind, the new 3-inch and 4.7-inch A. A. Gun Mounts, Model 1920, have been designed. By observing the photographs of the wooden models, which do not, however, include the trailer or self-propelled caterpillar element, respectively, a comprehensive idea of the general characteristics of the type of mount is apparent. The 4.7-inch mount is simply a magnification in dimensions of the 3-inch. A breech-trunnion gun, counterbalanced by means of the equilibrator, can be elevated from minus 5 to plus 80 degrees about the trunnion pintle. This pintle rests in a spherical seat, and is capable of movements of 5-degree amplitude for accurate leveling. The carriage has all-round traverse. The four jack-screws at the extremity of the outrigger arms are employed in lifting the weight of the unit off the spring of the chassis and also to level the trunnions approximately. A pneumatic loading device will assist in retaining a rapid rate of firing. Besides containing many novel features in carriage design, it also will be equipped with a sighting system that is considerable of an advance over any yet applied for the service. By virtue of differentials in the lateral and vertical sight mechanisms, the telescope observer will never lose the target when deflection corrections are being given the gun. The entire manœuvre of the gun, exclusive of loading, will be in the hands of four men, who perform their operations independently and without disturbance to one another. Each carriage is supplied with a wind and parallax dial and a telemeter attachment, thereby permitting wind and parallax corrections and fuse range to be obtained at the guns. The system is applicable either to direct or indirect firing. Illumination of scales is provided for night-firing operations.

The firing from anti-aircraft guns is high angle and, consequently, differs from that against terrestrial objectives by the large angles of sight for which the guns must be laid. The assumption of the rigidity of the trajectory—namely, that the arcs of the trajectories subtended by equal chords are identical, which can be made with sufficient accuracy in angles much above 15°. This occasions the introduction of a new term called "fuse range" that signifies a fictitious range expressed in graduations of the fuse setter at which the fuse must be set in order to produce a burst at a certain geometric distance and angle of sight. Unlike terrestrial practice where a certain length of powder train determines a definite range, in firing on celestial objectives the length of the train, which corresponds to the flight of the projectile from the gun to the bursting point, depends upon, first, the velocity of the projectile between those points, and, secondly, the rate of burning of the powder train. For the same range, these two speeds vary with the angle of elevation. The time of flight of the projectile for the same range becomes greater as the angle of sight increases, due to the corresponding augmentation to the action of the force of gravity along the trajectory. The rate of burning of the fuse being slower at the higher altitudes, because of the decrease in oxygen, means an increase in the time of flight. To a certain extent these effects counteract, but the net result is that, as the angle of sight is increased, the range to the burst is decreased, or the time of flight of the projectile for the same range becomes greater. In order to eliminate the factor caused by the irregularity in burning of a powder train, the positive functioning mechanical fuse finds application. The diminution in time of flight of the projectile can be accomplished either by increasing the muzzle velocity or changing the projectile design to the improvement of shell power, or both. In order to attain a more rapid rate of fire, the last of the three general requirements listed in the aforesaid, automatic fuse setters and mechanical loading devices will be phases of advance in the design of future anti-aircraft artillery equipment.

Prospectus of the Science of Anti-aircraft Gunnery

In spite of the infancy of the science of anti-aircraft artillery, more rapid advance has been made in the development of automatic apparatus to control its fire than in any other branch of artillery. Being the most precise form of gunnery, it requires material capable of the highest degree of facility and accuracy in the measurement and derivation of deflections. There is no field of artillery offering such a fascinating future to the scientific mind as that of anti-aircraft artillery.

The advent of aircraft opens a vulnerable field of invasion. It is a boundless one, its limitations being governed solely by the extent to which perfections in aircraft design will be carried in the future. The scope of its force admits the possibility of reaching every individual of the nation. In this regard it is unlike invasion from enemy fleets on the sea whose zone of immediate action is limited to locations along the coast. The necessity for protecting ourselves against any encroaching armies of the air, therefore, becomes a nation-wide requirement. Anti-aircraft gunnery to-day becomes the most vital branch of artillery service, and, accordingly, demands the very best of scientific research, practical equipment and well-trained personnel.

Anti-aircraft Units in Army

Although tables of organization for anti-aircraft regiments in the Army of the United States have been prepared in the War Plans Division, W. D. General Staff, there will be no regiment organized in the Regular Army. Should the plans for the organization of the National Guard and the organized reserves be adopted, anti-aircraft regiments for these components of the Army will probably be organized. For the Regular Army peace establishment a table of organization for an anti-aircraft battalion which would contain the three elements of an anti-aircraft regiment (anti aircraft gun, searchlights and machine guns) has been prepared and will probably be approved. The purpose of the War Department is to organize three such battalions as part of the coast artillery corps in connection with the fixed coast defenses. The war-strength tables of organization provide for anti-aircraft regiments with the three elements to which the battalions could be easily expanded.

Fig. 1. Range Stakes--Miami, Florida

Long Range Small Arms Firing

PART III

Experimental Methods—Miami, Florida

By

GLENN P. WILHELM
Member A. O. A.

AFTER the close of the Borden Brook range on account of climatic conditions, the Small Arms Ballistic Station was established at Miami, Florida. This range was similar to the Borden Brook range, in that the splash of the impact of the bullets on a smooth surface of water was the means by which the range and direction of the flight of the bullets were obtained. It differed from the Borden Brook range, in that the firing was done at sea level and over a horizontal surface. At Borden Brook the range measurement, as has been shown, was obtained by instruments at the gun position, thus requiring a very small personnel. At Miami, on the other hand, range measurements were made by observers located in observation towers adjacent to a long line of range stakes, the observation being direct. This, of course, required a larger personnel.

It was possible to obtain ranges at Miami from the main firing point up to 3,000 meters, and by means of an auxiliary firing point 1,400 meters in the rear it was possible to obtain ranges up to 4,400 meters.

The methods of obtaining the data at Miami, on account of the arrangement of the range and instruments, were entirely different from those of Borden Brook. The work at Borden Brook, insofar as the measurement of elevations was concerned, was characterized by an experimental determination of the error in the clinometer seat of machine guns, and an experimental determination of the angle of jump of the gun by means of bore sights and bore levels.

Screen Measurements of Elevation and Deflection

At Miami, measurements of elevation and direction of the beginning of the flight of the bullet were obtained independently after the bullet had left the gun, from the measurement of elevations on the gun. This was accomplished by means of a paper screen, through which the bullet passed after leaving the gun, thus enabling its elevation and direction of flight to be measured. Although at Borden Brook some screen firing was done, it was at Miami that this practice became general.

The reason for the screen method of measuring elevation and deflection being adopted was because it was found, in spite of careful measurements of the angle of jump, the clinometer seat error, and other variations, that the final line of departure of the bullet could not invariably be obtained by correcting the angular measurement of the elevation of the gun by the errors above enumerated.

With the paper screen, however, two independent measurements were taken, one being the elevation and deflection of the gun itself, corrected by the errors of jump, clinometer seat, etc., and the other measurement being that of the bullet's flight. This method of measuring marked a distinct step in advance of any method hitherto devised. The difference between the measurements made on the bullet itself by means of the screen, and the measurements made of the gun, would, of course, be the sum of all the errors, such as jump, clinometer seat, etc.

The method of making this screen measurement was by means of a large paper screen erected in the path of the bullets, 100 feet distant from the gun, the screen being large enough to show the passage of any bullet fired with the necessary elevations and deflections, from the shortest ranges up to about 2,200 meters, at which range the bullets would pass over the top of the screen.

At first a double screen was used, one being close to the muzzle of the gun. This muzzle screen was later discarded, as it was found to be unnecessary and as it appreciably slowed up the tests, besides introducing slight errors due to its effect on the bullet.

Use of Transits

The system finally evolved was that of setting up a small explorer's transit, capable of reading angles of elevation and deflection to the nearest minute of arc, so that the transit was on an arc of a circle whose radius was 100 feet, the center of the circle being the center of the paper screen. The pivot of the gun was also on the arc of this circle, the transit and the gun being separated by the shortest possible distance. The height of the horizontal line of sight of the transit was at the same level as the horizontal center line of bore of the gun. The zero of the horizontal circle of the transit in deflection was the same point on the screen as the zero of the deflection of the center line of bore of the gun barrel prolonged to the screen.

When a single shot was fired, or in the case of the machine gun a burst of shots, the cross-hair of the transit would be placed on the center of impact on the screen, and the transit man would directly record the transit elevation and deflection. These elevations were corrected by the calculated drop of the bullet for the time it occupied in reaching the screen at 100 feet from the gun. The error in reading the horizontal angle or deflection, on account of the parallax error introduced by having the transit at one side of the gun, was usually negligible for very small angles, because a lateral distance on the screen (a foot, for instance) will, of course, subtend the same angle at the gun as at any other position to the right or left of the gun up to a certain amount.

This system had the advantage of being very rapid, as the transit readings were taken as fast as the shots were fired, and, moreover, the screen gave a permanent record, so that if the difference between the measurement of elevations on the gun and those of the transit were great enough not to be accounted for by the usual errors, the transit readings could be verified.

Effect of Paper Screens

In order to determine the effect of the paper screen on the flight of the bullet, tests were made of the difference in impact at various ranges of bullets fired through the screen, and bullets fired through a hole in the paper at precisely the same settings. It was found that the ordinary standard target paper, backed by standard target cloth, at a distance 100 feet from the gun, has no appreciable effect either on the range of the bullet or its direction with small-arms ammunition, such as our service ammunition.

Use of Mann Rest

Another method of determining the exterior ballistics of bullets was by the use of the Mann Rest. This work permitted very precise measurements of both the center line of bore of the gun and of the transit as the transit was very close to the center line of bore. The instrument used in measuring the elevation of the center line of bore was the standard artillery quadrant, graduated to one minute of arc. The Mann Rest was particularly desirable for measurements of drift, as it was possible to fire alternately barrels having a right-hand twist rifling and those having left-hand twist rifling.

The Roller Screen

During the latter part of the firings at Miami a modification of the paper screen was made. This design consists of a roll of paper much thinner than target paper, mounted on rollers in such a way that the paper can be unrolled and wound up from the firing point, thus presenting a clean sheet for each range. It was possible to move the roll of paper, both laterally and up and down, so that the paper would always be in the line of fire. On account of the small size of the area of paper exposed to the wind, no backing by cloth was required. This eliminated any effect on the flight of the bullet, which occurred to some extent in the use of the .22-caliber rifle and other small caliber weapons.

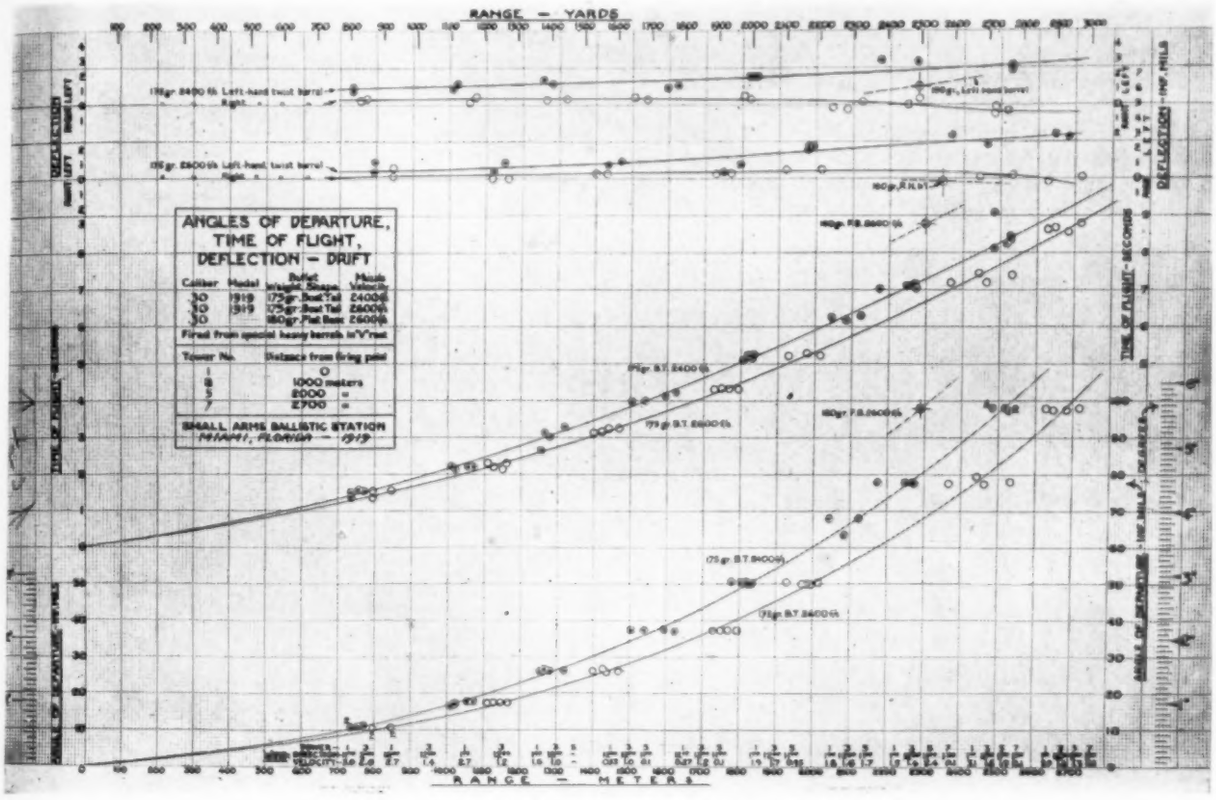

RANGE — YARDS
ANGLES OF DEPARTURE, TIME OF FLIGHT, DEFLECTION — DRIFT
SMALL ARMS BALLISTIC STATION
MIAMI, FLORIDA — 1919
RANGE — METERS

Fig. 2. Graph showing Plotted Results of Test to Determine Ballistic Data

Range Stakes

The method of laying out the range stakes is illustrated in Fig. 1. At every hundred meters the range was marked by white stakes with large figures which faced both the firing point and the observation towers. The 25-meter, 50-meter and 75-meter ranges were indicated by stakes colored red, black and green, respectively.

Observers, in determining the range, did so by estimation of the range to the splash of the bullet with reference to the range stakes, the center of impact of the shots being kept on or near the line of stakes to avoid parallax errors. The

greatest distance at which an observer had to observe shots was 250 meters, this point being the half-way point between observation towers. In all such cases double readings were made from two adjacent towers to avoid errors of parallax.

For single shots there was, of course, only one reading from a given tower, but for a machine-gun burst the number of observers on a given tower was increased, and the range observations recorded were the observed shortest shot, the observed longest shot, the estimated center of impact, and the estimated range to the long and short shots, excluding the longest and shortest shots.

Measurement of Deflection

Lateral deviation of the impact of the bullet on the water was obtained by instruments (usually transits) placed on the fire-control tower in rear of the guns. The zero of the transit azimuth coincide with the zero of the center line of bore and also of the zero in azimuth of the screen transit.

The angular lateral movement of the bullet in flight was always the difference between the original direction of the flight of the bullet, as measured by the screen transit, and the final direction of the splash of the bullet as shown by the transits on top of the tower.

Rapidity of Work

One of the greatest advantages of the range at Miami was the rapidity with which the work could be accomplished It was possible, within the space of an hour or so, to fire a test, enabling all the necessary data to be recorded from ranges from 200 meters up to 3,000 meters, thus eliminating the inconsistencies which usually resulted in experimental firings on account of changes in weather conditions.

Character of Experimental Data

An example of the character of the data obtained on the Miami range is illustrated in Fig. 2, showing a graph of a test fired to determine the angles of departure, time of flight, effect of wind, and the drift of two types of boat-tailed bullets at 2,400 and 2,600 feet per second muzzle velicities, respectively, for ranges up to 2,700 meters. A few shots were also fired with a flat-based bullet at 2,600 feet per second in order to show a comparison at long range.

This graph shows in detail the amount of data which could be obtained by one test. By repeating this test and other tests of a similar nature a great many times, enough data was obtained to determine with a very small probable error all of the information necessary for establishing the flight of the bulet from the muzzle of the gun to the maximum range.

Normal Elevation Curve

Fig. 3 illustrates how the angle of departure curve was obtained for service ammunition under normal wind conditions. This curve is made up of plotted points representing the center of impact of Browning Machine-Gun bursts which were fired under unusually calm wind conditions. These points were obtained by firing seven different tests, each test usually being fired on different days. The elevation curve, as determined by these points, is unmistakable, and the variation in the points themselves shows the probable error in range for a given elevation. The elevations determined by these tests were for ranges from about 950 meters up to ranges of about 2,800 meters.

Machine Gun Dispersion

During the operation of the Small-Arms Ballistic Station in Florida a great deal of data was obtained on machine-gun dispersion by firing on the smooth sand of Daytona Beach. The method of recording the data for this firing was as follows:

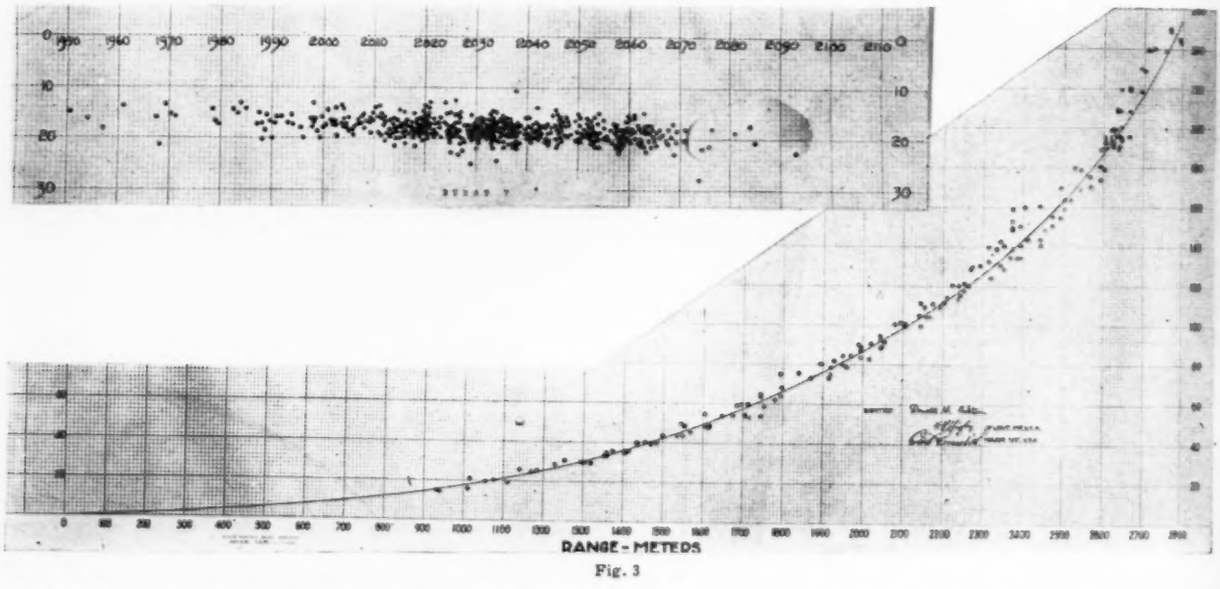


Fig. 3

The machine guns were mounted on service tripods and set up on T-bases in the sand. Sometimes the elevations were recorded entirely by clinometer, and sometimes both the clinometer elevations of the gun and the screen elevations of the line of flight were also recorded.

The shots, upon striking the sand of the beach, left a distinct mark. The necessary data for plotting these shot marks on the sand was obtained by the use of a transit and stadia in connection with a line of range stakes at 100-meter intervals. Since a later article will deal entirely with machine-gun dispersion, the question will not be discussed further at this time.

Experimental Methods—Ormond Beach, Florida

The most complete and extensive tests that were undertaken were carried on at Ormond Beach, Florida, during the spring of 1920. These firings were characterized by a final improvement in the method of obtaining the elevation and deflection, as the screen used at Ormond Beach was a

further improvement of the roller screen of Miami. A transit in the rear of the guns was used for the purpose of carefully determining the zero line of deflection, this transit being removed during the firing and the measurements being obtained by the transit to the right of the platform. The screen was so arranged with the necessary vertical and horizontal scales that the fire-control officer could at all times, by visual observation, read the actual elevation and deflection that was being secured on the shots. The screen was very readily adjusted for any elevation or deflection.

This firing point was later greatly improved for purposes of convenience. The range was practically unlimited in length. A line of range stakes, 5,000 meters long, was laid out at 10-meter intervals, and a range of twice that length was available if necessary. Observation dugouts were located along the line of range stakes every 300 meters.

Measurement of Shots

The method of measuring the location of the shots on the beach is illustrated in Fig. 4, which shows a range party from one of the observation dugouts measuring a machine-gun burst within its sector. Wire pins have been placed in each shot mark so that the co-ordinates of the impacts, with reference to the line of range stakes and the position of the gun, can readily be measured and recorded by means of a graduated tape and a right-angled prism.

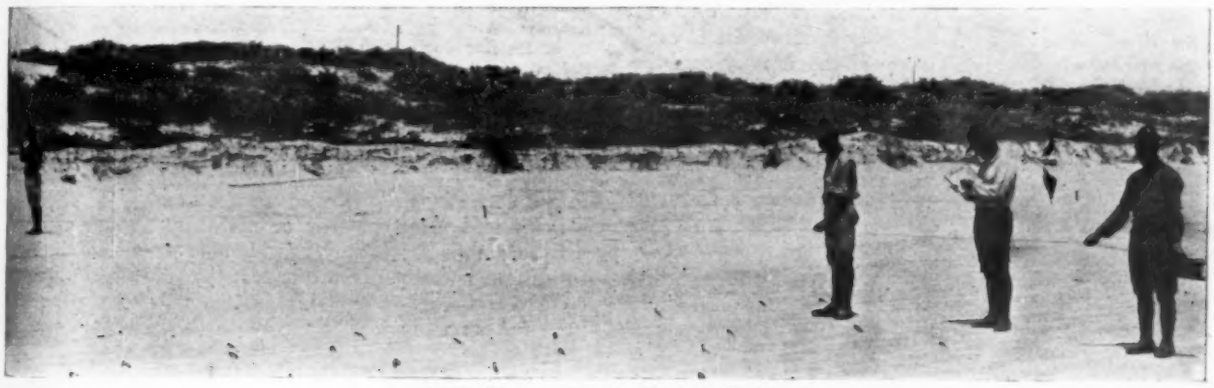


Fig. 4. Measuring Impact of Shots on Beach

The upper part of Fig. 3 is an actual record of a 500-round burst from a Browning Machine Gun firing service ammunition. The upper horizontal line of figures shows the range measurement at 10-meter intervals, the shortest shot being at 1,950 meters and the longest shot at about 2,090 meters. The vertical figures at the right and left show the measurement of each shot from the line of range stakes. In other words, the large squares are 10 meters on each side, each large square being divided into small squares 1 meter on each side. Each shot is therefore plotted to an accuracy of 1 meter.

Short Range Firing

In addition to the beach range at Ormond, which has just been described, there was also another experimental range parallel to the beach range, consisting of a firing point and screen. This range had the usual form of vertical targets at ranges of every 100 yards, up to 1,200 yards. This range was used for determining the necessary data up to a range of about 1,000 yards, after which the firing was transferred to the beach on account of the difficulty in hitting the vertical targets.

The method of determining elevations and deflections on the upper range was similar to that of the lower range, as far as the firing point was concerned. However, the elevations, as read by the transit on the passage of the bullet through the first screen, were corrected by the location of the center of impact of the shot group on the vertical targets with reference to the horizontal center line of bore prolonged.

Time of Flight

At Ormond Beach the method of determining the time of flight was necessarily different from that of Miami and Borden Brook.

The time of flight was obtained by using various methods. When firing through the vertical targets, microphones were attached to the target frame and to the gun base, making it possible for observers with stop-watches reading to one-hundredth of a second to determine accurately by sound when the bullet left the gun and when it passed through the vertical target. At ranges where it was impracticable to use vertical screens, microphones were buried in the sand, and the time of flight was obtained by hearing the sound of the discharge through the telephone and the sound of impact through the microphones. At extreme ranges, where shots could not be placed with sufficient accuracy to be heard through microphones, the time of flight was taken from the sound of impact on the beach.

In addition to the usual anemometers and wind-direction dials at intervals along the range, as used at Borden Brook and Miami for the determination of air currents affecting the bullet's flight, there were also used at Ormond Beach rubber pilot balloons, by means of which data was obtained upon the upper air currents.

Accuracy Obtained with Mann Rest

An example of the accuracy obtainable with the Mann type of rest, and also showing the possibilities of the screen method of determining data, is illustrated in Fig. 5. The first shot group, consisting of one hole slightly larger than a .30-caliber bullet, has been made by 10 shots of match ammunition which passed through a paper screen placed 100 feet distant from the gun. The second group shows the size attained by these same 10 shots at a range of 200 yards.

In other words, 10 shots fired with match ammunition, in which each bullet left at precisely the same elevation and direction, had separated at 200 yards sufficiently so that 9 of the bullets were still touching each other and the other bullet being only about ½ an inch off. This is probably one

(Continued on Page 350)

ARMY ORDNANCE

VOL. I MAY-JUNE, 1921. NO. 6

The Cost of Unpreparedness

ONE of our most widely circulated weeklies recently contained in a leading article the statement: "We are all familiar with the argument that the best way to prevent war is to be prepared for war." Continuing, it points out that from 1834 to and through 1919 the War and Navy Departments actually disbursed some twenty-nine billion dollars, and asks "whether any part of this twenty-nine billion dollars spent for preparedness and for war prevented our going to war or found us prepared when we went to war."

Twenty-nine billion dollars *for preparedness*, and, incidentally, oh, very incidentally, for war? Why so casually lump these items? Why by subtle juxtaposition credit preparedness with the lion's share of the artfully combined total? Do we lump fire losses with fire prevention and fire insurance, and rail at the cost of the fire department because, admittedly too small, due to our own neglect, it failed to stop a conflagration which caused us inordinate loss?

The leading editorial of the same issue suggests an explanation. We are flatly told "In time of war, a nation can not tolerate pacifism; in time of peace it must not tolerate militarism." And then we are solemnly informed that "War is bred by talking war and arming for it. In time of peace prepare for peace by talking peace and beginning disarmament." The congenital pacifist will, of course, believe what he wills to believe, but the average man will hearken back to our most recent experience in trying to talk ourselves out of a war which was eventually "thrust upon the United States," according to a certain joint resolution of Congress dated April 6, 1917.

Our entrance into the World War was not of our own choosing. A great wrong had to be righted, and note-writing and "talking peace" failing us, we righted that great wrong as we have righted other great wrongs in our past history—by force of arms.

Yet we need not actually to have used our arms or our army—*dynamic* force would not have been needed had we possessed the *static* force of adequate armament and sufficient personnel trained in its use. No less an authority than General Pershing has stated, after mature consideration, "It is my belief that if America had been adequately prepared, our rights would never have been violated nor our safety threatened." The consensus of intelligent opinion to-day is in entire agreement with our greatest military expert. Our forced participation was, then, directly due to our *un*preparedness, and it behooves us to look to the consequences and be guided thereby in future.

During the year ending June 30, 1920, over 8,000 officials and clerks (whose salaries, etc., amounted to more than $15,000,000.00) devoted their entire time to the administrative procedure incident to drawing on the Treasurer of the United States in payments on account of War Risk Insurance 5,641,831 checks aggregating $288,661,877.22, or about one million dollars for each working day in the year.

This total seems large until we consider that the Hon. D. F. Houston, Secretary of the Treasury, is authority for the statement that the aggregate net cost to us of the World War from April 6, 1917, to June 30, 1920, was $24,010,000,000.00, excluding loans to foreign governments and deducting all miscellaneous recoveries from war-time appropriations.

This staggering sum represents *the money cost of unpreparedness*—to include June 30, 1920, only! Unfortunately, we still have with us, and will have for years to come, a tremendous annual expenditure, of which this of the current fiscal year (ending June 30, 1921) is typical:

Obligations Arising from World War.

Treasury Department—	
Salaries and expenses, Bureau of War Risk Insurance and Farm Loan Board	$10,627,600.00
Collecting war revenue	21,535,000.00
Pensions	36,734.00
Military and naval compensation	210,000,000.00
Medical and hospital services	46,000,000.00
Expenses of loans	12,456,000.00
Interest on public debt	993,500,000.00
Sinking fund	253,404,864.00
Council of National Defense	120,000.00
National Advisory Committee (Aeronautics)	200,000.00
Shipping Board	442,599.00
Deficit during U. S. control of Railroads	800,000,000.00
Railway Labor Board	500,000.00
U. S. Housing Corporation	1,340,000.00
Federal Board for Vocational Education	111,836,000.00
Medical and Surgical History of World War	50,000,000.00
Artificial limbs	151,000.00
Deficit U. S. Control Telephone and Telegraph	14,000,000.00
Department of Labor (War Labor Administration)	39,912.00
Total	$2,476,240,209.00

Some idea as to whether or not these annual expenses will be diminished to any considerable extent in the near future can be gained from the fact that during the present fiscal year we are still paying *annually* the cost of participation in wars previous to the World War, as follows:

Obligations Arising from Previous Wars.

Pensions	$279,113,266.00
Interest on public debt	24,000,000.00
National cemeteries	22,024,329.00
National Homes Volunteer Soldiers	4,996,382.00
State Homes Volunteer Soldiers	1,000,000.00
Soldiers' Home (interest)	100,000.00
Soldiers' Home (permanent fund)	650,000.00
Extra pay volunteers war with Spain	3,000.00
Total	$331,886,977.00

From consideration of the above figures and the accompanying chart it will be seen that our present annual obligation arising from participation in wars for which we were unprepared is to-day requiring the expenditure of 59.2 per cent of our entire national budget, whereas but 8.8 per cent is being appropriated for military purposes and 9.5 per cent for naval purposes, a total of 18.3 per cent for preparedness.

Twenty-six billion dollars for *un*preparedness is a high price to pay, but the money cost is but part of the bill. The 77,000 gallant lads who gave their lives and the 225,000 who suffered disabilities to achieve the same results that we could have effected by reasonable preparedness are those upon whom fell the real, the *blood cost* of *un*preparedness.

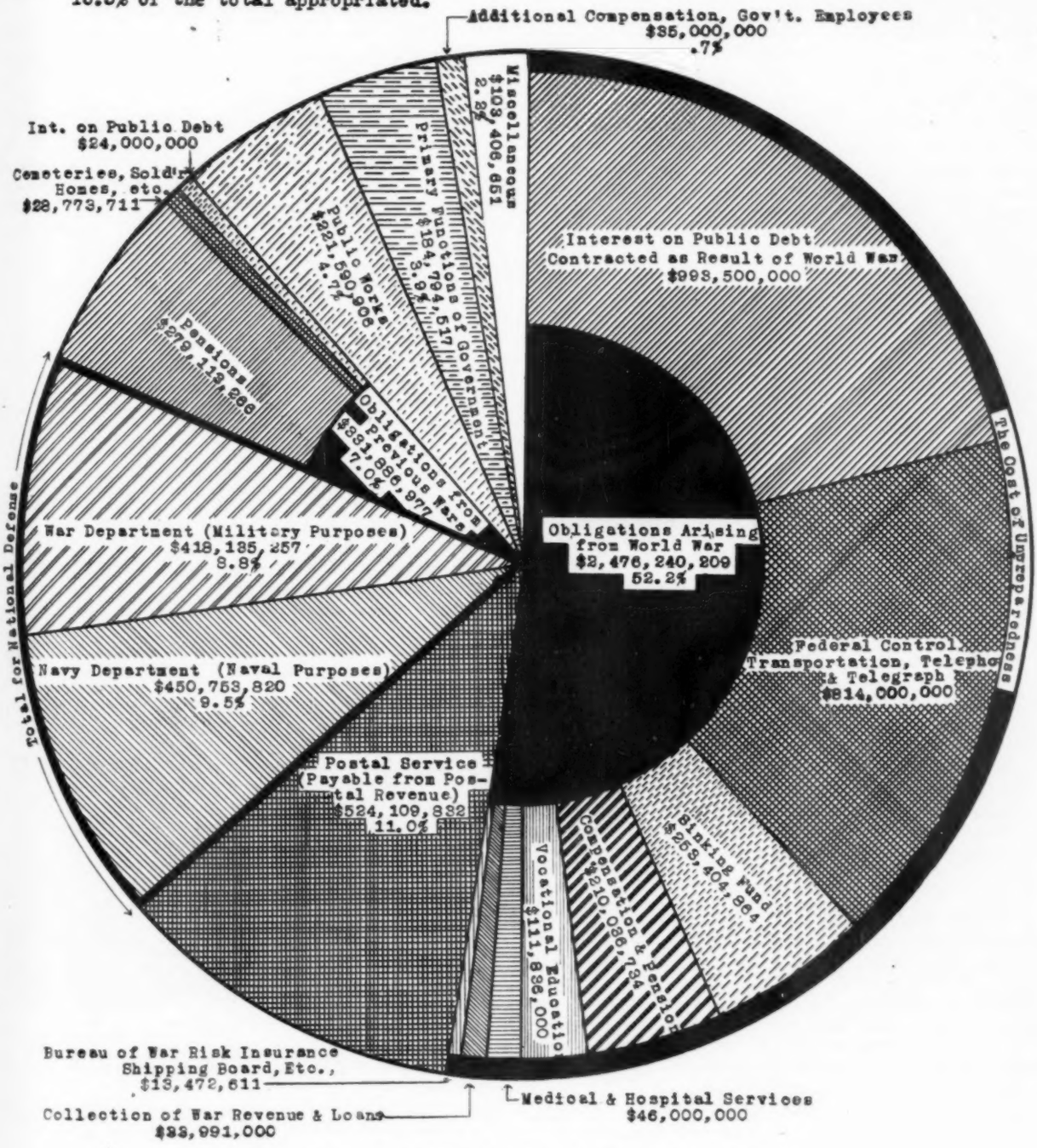
Because we have just been visited with a great conflagration which caught us inadequately equipped with the means to extinguish it, shall we decry fire prevention and fire insurance? Because we have lost in the holocaust thousands of brave lives and disabled hundreds of thousands of youthful bodies—we are spending $151,000,000 for artificial limbs this year—shall we doom our sons to similar fates in the future? Lacking the omniscience of some of our lead-

ing magazine writers and editors, the average American has no better guide for the future than dispassionate examination of the past. Let us pay the cost of our *un*preparedness—the money cost—and thank God we have not paid it with our limbs or our lives, and, for the sake of our future generations, if not for our own sakes, let us recognize that the world to-day is not Utopia; nor is to-day the happy millenium of eternal peace. "Talking peace" as a panacea for international ills has been weighed in the balance, and found wanting. Reasonable preparedness in the future will discount the unbearable totals of our latest folly. Millions for preparedness now will not only save billions for *un*preparedness eventually, but will obviate the useless sacrifice of our youth—*the real cost of unpreparedness!*

APPROPRIATIONS - FISCAL YEAR 1921

Source of information: Digest of Appropriations 1921; Treasury Department.

An analysis of the appropriation for the Fiscal Year 1920-1921 shows that the amount appropriated for Military purposes was $418,135,257 the amount appropriated for Naval purposes was $450,753,820 a total of $868,869,077 for National Defense, 16.3% of the total appropriated.



Unpreparedness in 1917 cost U S over Two Billion Dollars during the fiscal year 1921

THE SMALL ARMS DIVISION
RIFLES ★ MACHINE GUNS ★ AUTOMATIC RIFLES ★ PISTOLS ★ REVOLVERS
HELMETS ★ TRIPODS ★ SMALL ARMS AMMUNITION AND TARGETS
★ ★ ★ TOOLS ★ ACCESSORIES AND CONTAINERS ★ ★ ★

LONG RANGE SMALL ARMS FIRING

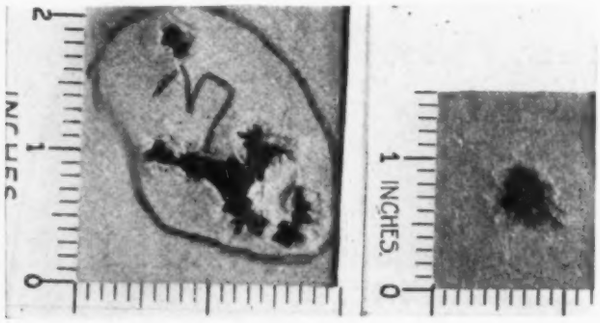
(Continued from Page 347)

of the smallest shot groups that has ever been obtained at a range of 200 yards.

Conclusion

Although the Borden Brook and Florida ranges were especially selected as representing the best possible conditions under which long-range small-arms firing could be held, each range was subject to certain limitations and drawbacks.

The Borden Brook experiments, on account of the general barometric conditions peculiar to a locality at a considerable elevation above sea level, were not ideal. Moreover, the use of this range necessitated inclined firing, thus introducing an error, the probable amount of which depended upon the



Range 200 yards — Range 33 yards
Ten Shot Group--Match Ammunition Fired from Mann Rest

error in the assumption of the rigidity of the trajectory. However, a comparison of the results obtained at Borden Brook with those obtained in Florida shows that this assumption was well within the other experimental errors.

The range at Miami, being a water range, as was also Borden Brook, sacrificed a permanent record of the impact of the shots for rapidity in completing tests.

The Daytona and Ormond Beach firings, on the other hand, embodied the greatest possible accuracy, but were under the greatest disadvantage on account of the slowness with which it was necessary to conduct the tests.

Criticisms

Criticisms of these firings are usually confined to the method of determining the time of flight and the variation obtained in the ranging ability of small-arms bullets at long ranges in different tests.

Such criticisms can be refuted by a careful study of the available data, which will show the essential requirement of these experiments to be rapidity in the completion of individual tests in order that variations due to meteorological conditions will affect the entire test equally.

The only way in which consistent results were obtained was through close adherence to the above system and to the careful record kept of the weather conditions, so as to allow a comparison of one day's tests to be made with those held on other days.

This alone prohibits the use of the electric chronograph for recording time of flight, as (admitting that it might be possible to determine long-range time of flight by bullet contact with screens) the time occupied in accomplishing this would limit the data obtained to a few ranges each day.

The personal element entering into the determination of time of flight by direct observation subjects this data to a considerable error. Whatever this error may be, it can be shown that it is well within the other experimental errors at the ranges in question, as the times involved vary from never less than 1½ seconds up to, in some cases, as great as 20 or more seconds.

Small-arms ammunition at long range is subject to considerable variation, just as it is at short range, and any other system of firing will probably show at least as great, or greater, inconsistencies as any developed during the Florida tests.

Centrifugal Gun

The centrifugal gun, which has been under investigation and test for some time by the Ordnance Department, was further tested at Aberdeen Proving Ground, Maryland, at a speed of about 16,000 revolutions per minute. At this speed it required 98 h. p. to operate.

The gun as tested showed a very rapid increase in the power required for operation. At a speed of 12,000 r. p. m., 20 h. p. was necessary; 14,000 r. p. m. required 25 h. p.;

Centrifugal machine gun being demonstrated by its inventor

15,000 r. p. m. required 40 h. p.; and, as noted above, at 16,000 r. p. m. the power required was 98.

From this it is concluded that a horsepower above 100 would have no material effect in increasing the speed.

In testing the gun it is noted that the muzzle velocity was approximately 10 per cent of the r. p. m. of the rotor; that is, 1,000 feet per second for 10,000 r. p. m.

The angle of dispersion was about 30°, and the rate of fire at 10,000 r. p. m. was approximately 1,140 rounds per minute. Penetration was sufficient at 250 yards to effect a disabling wound. In an accuracy test 2,000 rounds were fired at a screen at 50 yards. The main group of hits formed a rectangle of 7 by 10 feet, and the extreme dispersion covered an area still greater.

Indications do not point to the possibility of obtaining a centrifugal gun which will have any military value, by reason of the necessary weight and the apparent inability to obtain a sufficient initial velocity.

The tests which have been conducted are believed to furnish a basis upon which it may be definitely stated that this type of weapon is not suitable for development to a point where it will have military value. It is considered as an interesting illustration of what may be done with centrifugal force, but limited by the nature of the mechanism required to the status of a laboratory demonstration.

Springfield Armory Notes

Material Tested.

A test was held of one barrel for the Browning rifle having four grooves similar to the Springfield form, and one having five grooves similar to the 1917 form, both barrels rifled with a twist increasing from one turn in 59 inches at bullet seat to one turn in 10 inches at the muzzle.

Two barrels similar to the above for the Browning machine gun.

Object of Test.

The object of the test was to determine whether or not rifling with increasing twist has any advantage over the regular rifling with uniform twist in regard to erosion and wear on the barrels of machine guns and automatic rifles.

Program of Test.

The barrels were tested for erosion by firing them until the accuracy life was gone. The following data was taken at the beginning of the test, and after every two thousand rounds up to six thousand rounds, and for every one thousand rounds thereafter.

Velocity. The mean of ten shots at fifty feet from the muzzle.

Wax casts. These will show the bullet seats.

Accuracy. To consist of three targets of fifty shots each fired at a screen 100 feet from the muzzle while the gun is still hot. For this firing automatic fire will be used. Vertical and horizontal dimensions of these groups were measured and recorded, and photostats are attached to the report.

No star gauge measurements were taken as there are no gauges on hand to fit this type of rifling.

Examination of barrels. At the completion of the test all the barrels were sawed open lengthwise and photographed.

Details Regarding Test.

The machine gun barrels were tested in the Browning machine gun mounted on a Model 1918 tripod set on a T-base and held by three sand bags. A continuous stream of water was kept flowing through the water jacket at all times except when firing the accuracy targets. In firing the automatic rifle barrels a Browning rifle was used mounted on an adapter on a Model 1918 tripod and held by three sand bags. The barrels were cooled with water after every 100 rounds.

The two machine gun barrels gave an accuracy life of 7,000 rounds, which is not quite as good as that of the average service barrel. Bullets fired through these barrels showed a widening of the grooves which is the necessary result of the fact that the angle of the lands changed considerably from one end of the barrel to the other. This change of angle of the lands causes a pronounced widening of the grooves on the bullet and allows gas escape, which undoubtedly increased the erosion to some extent. It is possible that the change in the angle of the lands also increases the friction on the bullet.

The results obtained with the Browning rifle confirm these obtained with the machine gun.

In all the barrels metallic fouling was greater than in the service barrels.

There was no noticeable difference in the performance of the four and of the five-groove barrels.

It is the opinion of the Experimental Department that the rifling with accelerated twist when used with high velocity ammunition and jacketed bullets is not as satisfactory as the rifling with uniform twist now used in service barrels.

Other tests and reports have been completed at Springfield Armory during the past two months, as follows:

Report of test on Caliber .45 Pistol Bullets with Alloy Coated Steel Jackets.

Report on "Coloring and Finishing Small Arms Parts."

Report of remodeled Baldwin Aircraft Gun on vibrating stand.

Preliminary report on erosion tests on barrels for Browning Machine Guns made from Invar Steel.

Report of test of Lots 660 and 661 Frankford Arsenal ammunition.

The following information in regard to the origin of the Caliber .22 rifle which Springfield Armory is building may be of interest:

The rifle was started at Springfield Armory about 1915, but was stopped during 1917 on account of the war, and was resumed on February 25th, 1919. It was not known that any commercial firms contemplated putting out any rifle of this general type, until about six months later two commercial firms showed .22 caliber bolt-action rifles at Caldwell, N. J. However, this fact did not influence Springfield Armory in the design of the rifle as all parts of our .22 were made from regular 1903 rifle parts as far as practicable. The mechanism of our rifle is entirely different from that of either of the commercial rifles referred to above, and the bore and chamber dimensions of our rifle are different from any other rifle on the market and were arrived at after careful experiments, made at this Armory.

The rifle is patterned after the Caliber .30 Service Springfield rifle and only such changes have been made in the latter rifle as were found necessary to adapt it for firing the caliber .22 long rifle cartridge.

The development work on the 37 mm. Aircraft Automatic Cannon, which has been in process at the Springfield Armory for a number of months, has been accelerated in order to accede to the requirements of the Air Service. The present model, incorporating many improvements over earlier types, has been fired many hundreds of rounds with satisfaction. The cannon has now been developed to a point where it is ready for demonstration and test before officers of the Air Service, and such test is to be held on February 28th at the Aberdeen Proving Ground.

Major Earl McFarland was sent to McCook Field, Dayton, Ohio, to confer with officers of the Engineering Department of the Air Service in reference to the requirements of Automatic Airplane Cannons of the 37 mm. type. The Air Service attaches great importance to the development of this or a similar weapon and is impressed with the necessity of mounting such a gun on airplanes in order to study and discover the possibilities and various tactical uses to which such an arm might be put.

In the absence of a plane on which the 37 mm. cannon can be mounted for the Aberdeen test, it is anticipated that low temperature test of the cannon will be conducted in the Air Chamber of the Bureau of Standards.

The interest of the Air Service in an arm of this type leads to the possibility of further development along this line.

Huron metal, a patent composition of aluminum, copper, magnesium and manganese, is being extensively used in the newer carriages that have been manufactured for the 37 mm. Aircraft cannon. An interesting development in the use of this metal is seen in the effort to use castings instead of forgings for this work. In order to get sufficient strength for the trunnions it was necessary to cast the Huron metal around bronze trunnions already manufactured and set in place in the mould. The casting appeared sound and very promising. All the machining cuts were taken without trouble and a substantial saving in cost as compared with machine operations necessary when using a forging. If firing tests prove the efficiency of the combination of bronze and Huron metal castings, it is believed that the usefulness of Huron metal in ordnance design will be tremendously enlarged.

The Bridgeport District Ordnance Office has recently been discontinued. All of the activities of this district will be transferred to the Springfield Armory and will be placed under the jurisdiction of the Commanding Officer. The Bridgeport Office was one of the first district agencies organized by the Ordnance Office during the war and has a history of commendable and noteworthy accomplishments. The district was originated when Colonel Bascom Little, in the fall of 1917, was sent to New Haven to assist in the co-ordination of the various manufacturers undertaking the production of Browning Machine Guns. The office was later reorganized and the activities greatly extended by Mr. Waldo Bryant. It was continued by Colonel B. A. Franklin, now Vice-President of the Strathmore Paper Co., Mass., who organized the post-war activities and settled the many millions of dollars of claims received in this district.

The move to Springfield Armory will include the remaining activities of the Claims Board, Salvage Board, Property Division, Finance Division and Contract and Cost Accounting Section.

ARTILLERY DIVISION NOTES

Equilibration.

In the earlier types of gun carriages the tipping parts were trunnioned at their center of gravity, thereby permitting elevation or depression with a minimum of work. The recoiling parts of these earlier carriages did not strike the ground at maximum elevation, owing to their short cannon, short recoil and moderate elevation. As elevation and length of cannon were increased to meet demands for greater range, designers were confronted with the problem of providing space to receive the recoiling parts.

The obvious means of preventing the recoiling parts from striking the ground was to dig a hole to receive them, and this was done and is being done at present. But as artillery has developed, this method no longer answers all demands, and additional means were devised as follows:

1. Weighting the breech and thereby shortening the distance from the trunnions to the breech face.

2. Using a variable recoil mechanism and so shortening recoil at high elevations.

3. Using equilibrators.

The Germans and French used equilibrators on some of their carriages employed in the World War, but not very extensively. However, the demands of modern artillery have become so drastic in this regard that they can only be met by use of equilibrators on practically all field carriages.

Fig. 1 shows the cross-section of a spring equilibrator. A is the shell having the trunnion B. C is the plunger. D is a spring column under compression which tends to force A and C apart.

Fig. 2 shows the application of the equilibrator to the 155-mm. Howitzer Carriage, Model 1920. The tipping parts E, with center of gravity at F, are trunnioned at G upon the top carriage J. A pair of arms H fixed to the trunnion G receive the equilibrator trunnions at B. The plunger C sockets in the bracket K from the top carriage J.

FIGURE 1.

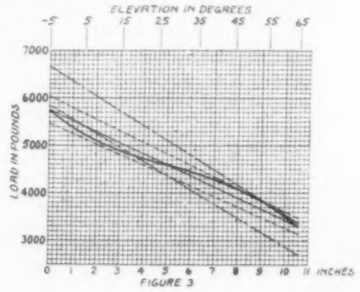


FIGURE 3

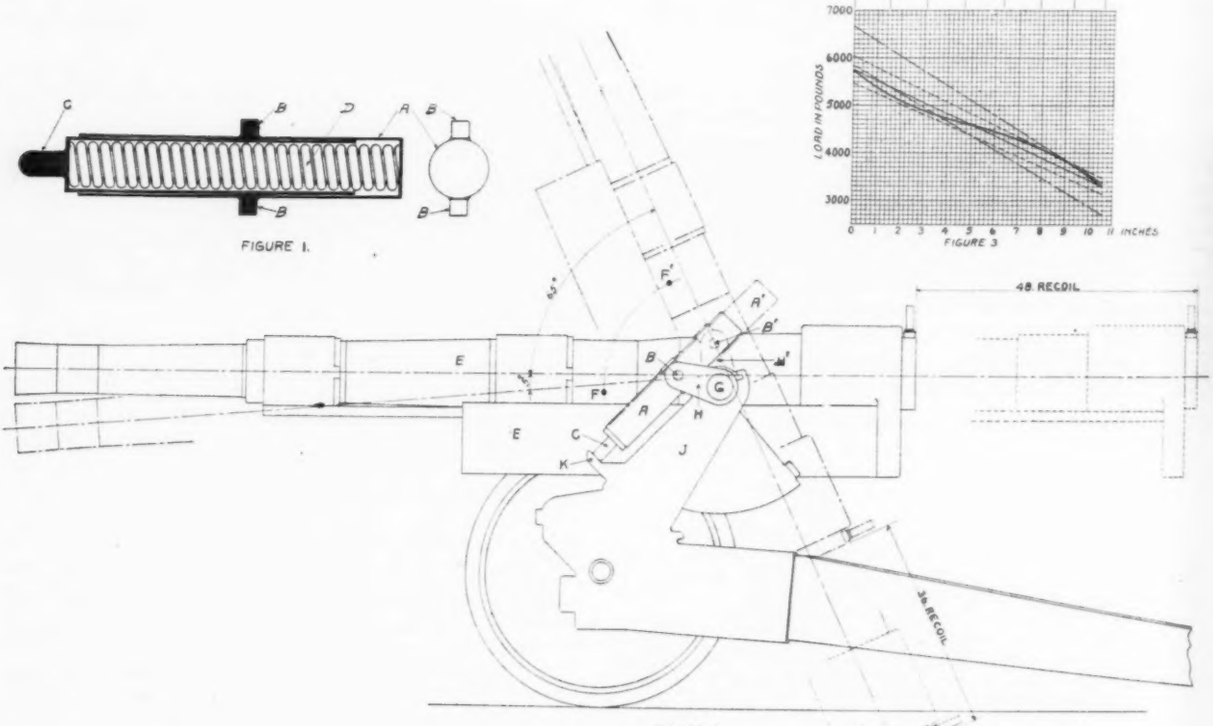


FIGURE 2.

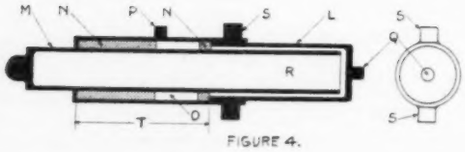


FIGURE 4.

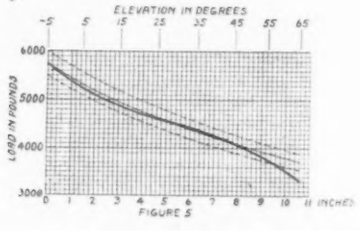


FIGURE 5

Gravity tends to pull the point F downward about G, which tendency is resisted by the equilibrator through the arms H.

Fig. 3. The heavy full curved line shows the spring load desired if the moment of the tipping parts is to be balanced in all positions. The light full line represents very nearly the actual spring load if a perfect spring were obtainable. The dotted lines show maximum and minimum spring loads, allowing a tolerance of plus or minus 5 per cent. The dot and dash lines show test loads on two springs which have been received.

Difficulties have been encountered by the Ordnance Office in obtaining equilibrator springs, owing to the severe specifications necessary. A high fiber stress is required to limit size and weight, and uniformity of section and material is essential in the bar in order to meet the specifications. It is necessary that the springs operate within narrow limits in order to secure the delicate balance absolutely essential.

In view of the irregularities found in springs, the Ordnance Office has designed a pneumatic equilibrator which is being built and which will be tested in comparison with the spring type.

Fig. 4 shows a cross section of the pneumatic equilibrator, which consists of a shell L with trunnion S and a plunger M. The space R contains compressed air, which is held by the packing N with a grease seal in O. P is a valve to admit grease, and Q is a valve to admit air. The shoulder in L limits the packing length T so that proper volume of air is assured. The air pressure in R tends to force the plunger M out of L. This equilibrator is interchangeable with the spring equilibrator on the carriage.

Fig. 5. The heavy full curved line shows the desired pneumatic equilibrator load. The light full line shows the load obtained. The dotted lines show the load obtained plus or minus the packing friction. It should be noted that this packing friction is the most objectionable factor of the air equilibrator. This friction works in both directions of movement and can not be compensated for. It is therefore necessary that it remain within narrow limits, and it is hoped these limits will be less than the tolerances required in spring manufacture. It is believed this can be done.

Motor Mount Tests.

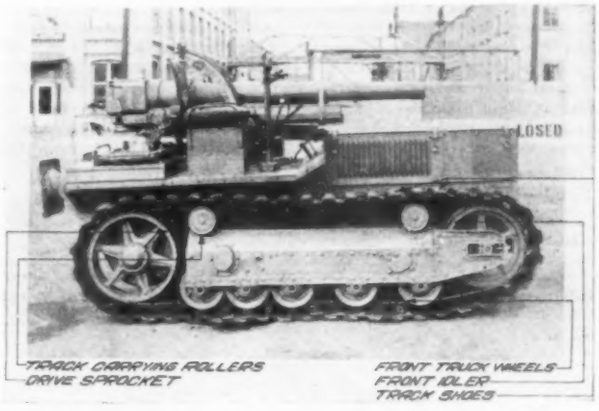
Two experimental caterpillar type motor carriages for the 75-mm. gun and 105-mm. howitzer, Model 1920, built by the Holt Manufacturing Company, Stockton, California, have just been successfully proof-fired at Fort Scott, California. These mounts made the 120-mile march over the mountains from Stockton to San Francisco, California, at a normal running speed of 15 miles per hour and a maximum of 30 miles per hour.

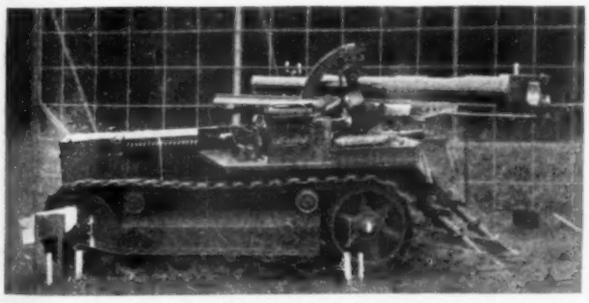
This new "Racing Cannon" received an enthusiastic greeting upon arrival in San Francisco, where it was officially welcomed by Mayor Rolph and christened with real champagne by Mrs. Rolph, wife of the Mayor of San Francisco. The citizens of California are justly proud of this new development of artillery, a product of their State.

These two new mounts performed excellently during their firing tests and showed wonderful stability. Mr. Pliny E. Holt, of the Holt Manufacturing Company, pulled the lanyard for the first shot fired from this new mount. The illustration shows the howitzer in recoil position.

High-Speed Features of Motor Mounts.

The two motor carriages for the 75-mm. gun and 105-mm. howitzer, Models 1920, which have just passed very successful proof-firing tests





105-mm. howitzer being fired from self-propelled mount, which attained a maximum speed of 30 miles per hour en route from Stockton to Ft. Scott, Cal.

at Fort Scott California, were able, during the road tests, to develop a maximum speed of 30 miles per hour. These two experimental caterpillar gun mounts were designed and built by the Holt Manufacturing Company at Stockton, California. This is the highest speed for a caterpillar-track machine that has ever been obtained, and the well worked-out features of design which permit this speed are very interesting.

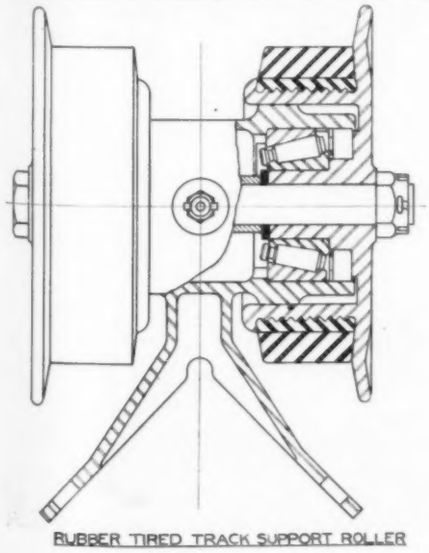
The four principal features of the track mechanism on these mounts are:

1. The use of rubber to reduce the jar and absorb the road shock before it reaches the vital parts of the trucks and the tracks.

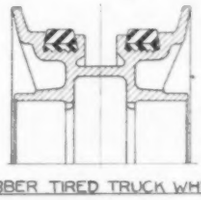
2. Light-weight tracks, which, due to the reduced inertia of motion, reduce the forces on the track parts.

3. Entire mount spring-supported with perfect equilization between the tracks and the main frame, which takes all shocks from the main frame, engine and transmission.

4. Long tracks lying flat on the ground and with rubber tires on the front truck wheels. This causes each track to rise in front, where it is light, on account of being well ahead of the center of gravity, over each bump and then the heavy parts follow up a gentle slope. If a

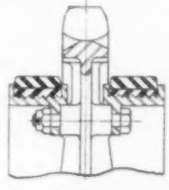


RUBBER TIRED TRACK SUPPORT ROLLER
FIG. 1



RUBBER TIRED TRUCK WHEEL
FIG. 2

RUBBER TIRED FRONT IDLER
FIG 4



RUBBER TIRED TRACK SPROCKET
FIG 3

TRACK SHOE
PARTIAL SECTION SHOWING RUBBER PAD
FIG 5

series of bumps come at close intervals, say three or four feet apart, the track bridges the bumps and smooths the path.

Going over these features more in detail:

1. The rubber is used on the track shoes, front idlers, track-carrying rollers, drive sprockets, and front-truck wheels. Figs. 1, 2, 3, 4, 5 show the method of application.

2. The track links were designed with as light sections as permissible, the part of the shoe farthest off the ground being only one-eighth of an inch thick. Cast steel with a carbon content of .30 to .40 is used, and then double-heat treated to obtain an elastic limit of 60,000 pounds per square inch. The bushings are very thin and the track pins large in diameter and hollow, both being made of forged steel, case hardened, to give a surface hardness of 75-85 scleroscope.

3. The main frame is spring supported to the trucks both front and rear. Coil springs being used in the rear and a plate spring in front. This plate spring is hung on a trunnion in the center under the engine and forms the tilting member of an equilizer between the front ends of the two trucks. The novel feature of the equalizer is the use of cranks to guide the trucks in planes always parallel to the main frame of the mount. One end of each crank turns in fixed bearings in the main frame, while the other end passes through its respective truck frame and is hung to it by a short link to take up the longitudinal motion of the crank pin. This equilizing system allows the front of one truck to rise 15 inches above the other.

4. The long single truck frame, without joint or flexibility in its length, is probably the feature which most largely contributes to the successful high speed.

It may help to visualize the action of this feature by imagining a sportsman on skis racing down a snow hill which might be quite rough locally, but the rough places are spanned by the long runners and the man glides smoothly along.

Anti-friction bearings used on all revolving shafts, except in the engine, reduce the rolling friction to a minimum. The high speed is then obtained without excessive power in the engine.

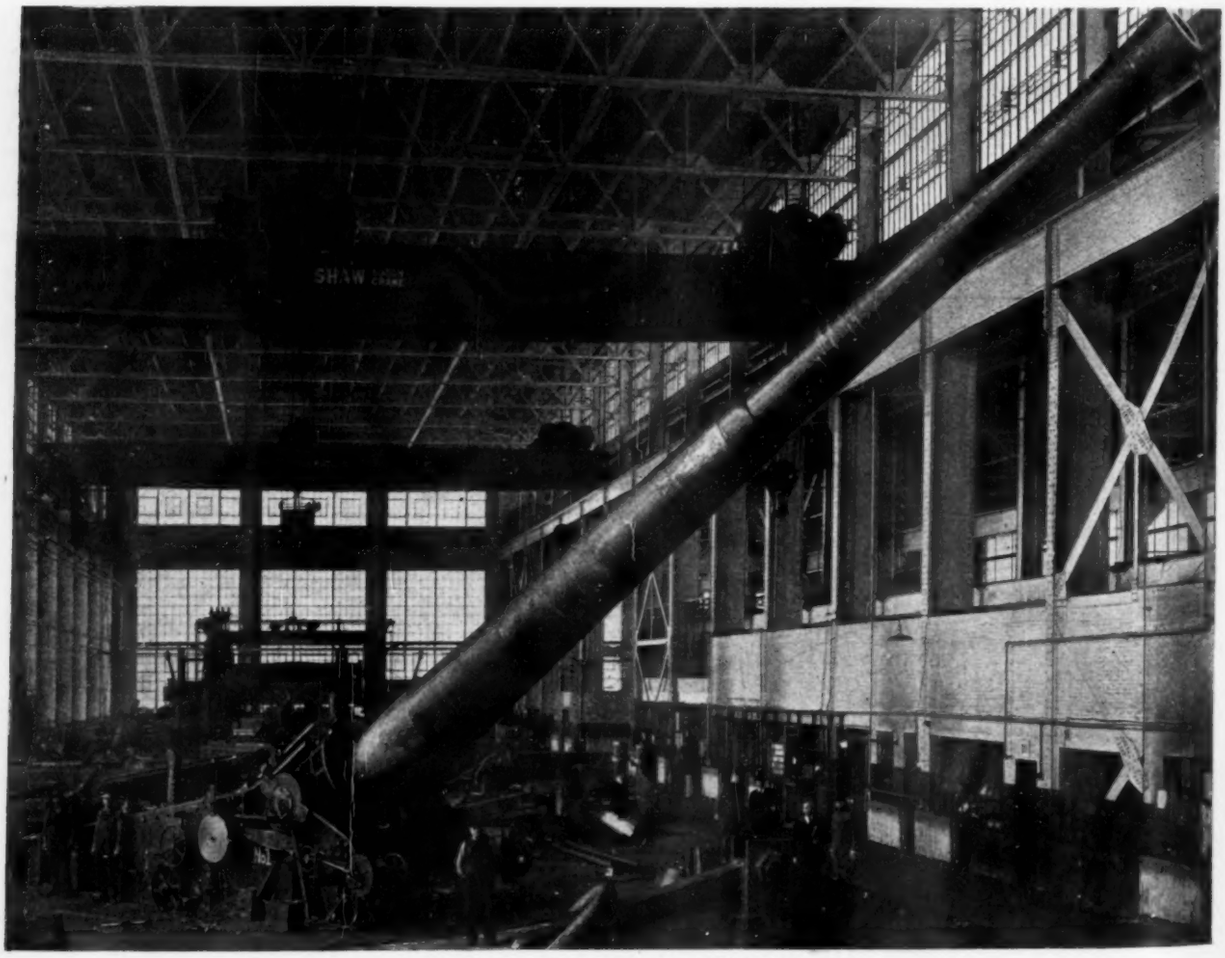
Sixteen-inch Barbette Carriage.

The shop test of the new 16-inch barbette carriage, recently completed at Watertown Arsenal, was witnessed by representatives of the Railway and Seacoast Carriage Section, Artillery Division, designers of this matériel.

The carriage was put through the usual tests and functioned very satisfactorily. The load required at the slow-motion hand-wheel to traverse the piece was 17 pounds. The gun was elevated from zero degrees to 60 degrees in 27 minutes, using man power. The electric traversing and elevating equipment has not yet been assembled to the pilot carriage.

The gun was also snapped, using the new device described in these notes at zero degrees, 34 degrees and 65 degrees, the gun returning fully to battery, at each elevation. Very satisfactory pressure cards were obtained at all elevations, showing that the new counter recoil mechanisms, which were especially designed for this carriage, had sufficient power to control the counter recoil of the gun at low angles of elevation. One of the most difficult problems in the design of this new carriage, which permits the maximum angle of elevation of 65 degrees, was the control of the gun, which, with its recoil band, weighs about 200 tons, in counter recoil at low elevations. An automatic counter recoil mechanism is necessary which will do a large amount of work at low angles of elevation, but which will do little or no work at the higher angles. The new system appears to give complete control at all angles.

This new weapon will have all-round fire and an estimated range of 55,000 yards, with a 2,340-pound armor-piercing projectile. The penetration of armor is 14 inches or more at all ranges.



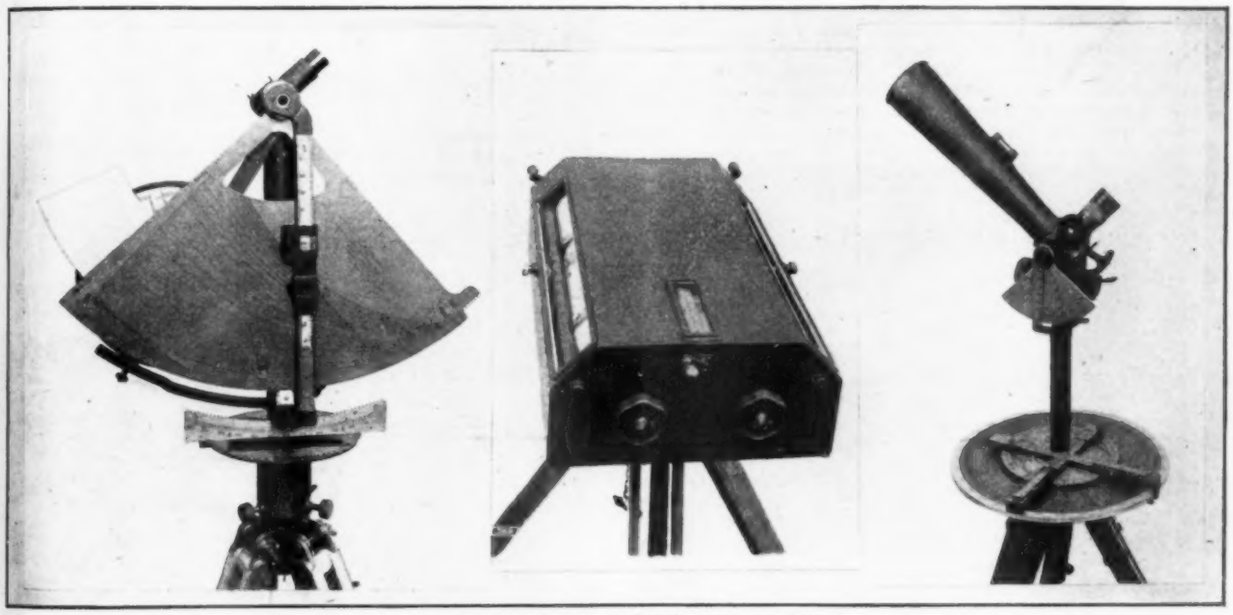
Sixteen-inch Barbette Carriage, Model of 1919

FRANKFORD ARSENAL NOTES

Anti-Aircraft Fire Control.

The three instruments shown in the illustration included herewith have recently been produced by the Fire-Control Design Section, Frankford Arsenal, for use with anti-aircraft artillery.

The Range Computer, at the left, accomplishes its function of the angle of sight and altitude to the predicted future position of the target, the resolution of fuse range. The operator, in following the flight of the airplane by means of the telescope, simultaneously elevates or depresses the photo-engraved sector that moves behind the altitude arm. This establishes laying to the present position of the target. At the back of the instrument is a mechanism, known as the corrector, which, by virtue of the relative movements of its elements, causes a displacement of the altitude arm away from its vertical or zero location. This movement, which is called the vertical deflection correction, is proportional to the displacement of the target during the time of flight of the projectile to the predicted future position of the airplane. Therefore, the combination of movements of the sector and the arm results in the determination of fuse range to the predicted future position of the target by reading the abacus beneath the index pointer of the slider, which is set to the graduation of altitude on the arm. An azimuth circle is provided to obtain the lateral indication of a target position for other instruments of the fire-control station, so that a certainty of all apparatus viewing the same airplane is preserved. The instrument is located at the B. C. Station, where three men are required to operate it. The reading of fuse range is telephoned to the gun emplacements.



New Anti-Aircraft Artillery Fire Control Apparatus

The deflection computer, in the center, serves two purposes in application to anti-aircraft artillery:

1. Computes both the lateral and vertical deflection correction data when the method known as linear speed is employed.

2. Provides the means of compensation for those corrections in the angular travel method required, because of the non-uniform velocity of the target. In this regard it serves as an auxiliary device with the Brocq A. A. Corrector.

Th accomplishment of these aims is satisfied by wrapping two composite sets of abaci around each set of cylinders. The plotting of the abaci, the location of scales and the relationship of these on the major and minor size cylinders of each set is in accordance with formulæ developed for the resolution of the deflection corrections. In short, the instrument may be considered as consisting of two graphic slide rules, one for computing lateral and the other vertical deflection corrections. The units are contained within an aluminum case and require two men to operate them. The resulting mile readings are announced, usually by telephony, to the gun emplacements.

The A. A. telescope, with wind and parallax computer, is shown at the right. It performs three functions:

1. *Telescope.*—This element is used to distinguish the target and, by continuous observation upon it, to follow its flight, thereby registering present angle of sight and azimuth. It is equipped with two eyepieces, one having a magnification of 10 and the other of 25. The roof prism is shifted by means of an external lever to alignment with either eye piece desired.

2. *Wind Computer.*—This element resolves the lateral and vertical corrections for wind. It comprises the smaller of the two dials mounted beneath the telescope. Setting the sliders to the scales of the two shorter arms establishes a location of each index pointer, against which the reading of the abacus upon the dial can then be made. The relative movements of these various elements is in accordance with the variables in the equations for wind corrections.

3. *Parallax Computer.*—This portion determines the parallax corrections with respect to its position in the B. C. station and the mean point between the guns of the battery. Like the wind computer, it consists of an abacus dial, a ring concentric with the upper disk, and two arms containing graduated scales and movable sliders. Their relative movements resolve the equations for the parallax corrections.

When operating both the wind and parallax computer elements, three men are required in the functioning of the apparatus. Their results are used as secondary settings, either on the central station apparatus or on the gun scales.

Each instrument described in the foregoing has been manufactured with the aim to obtain a very high degree of precision in the final resolution of the data which they give. The shop tests indicate that unusually good results are obtainable when trained personnel operate the instruments. The errors in the determination of deflections can be held within three mils and fuse range within three-tenths of the least setting of the graduated ring of the fuse setter, a discrepancy corresponding approximately to six hundredths of a second time of flight of the projectile.

Range Correction Board.

The Range Correction Board shown in the accompanying illustration was developed at Frankford Arsenal for the purpose of meeting the needs of the new long-range seacoast artillery guns, to which the existing Pratt Range Board could not be adapted on account of the great increase in dimensions which would result.

In the case of the Pratt Range Board, the curves giving the range corrections for atmosphere, muzzle velocity, tide and wind are all placed on one large chart, the size of which determines the dimensions of the complete instrument. Since the scale of these curves must be made sufficiently large to permit the various pointers to be set by eye, it is evident that any great increase in the ranges used has the effect of increasing the size of the board.

To overcome this difficulty and to keep the instrument within a reasonable size, the range correction board, model of 1921, was developed,

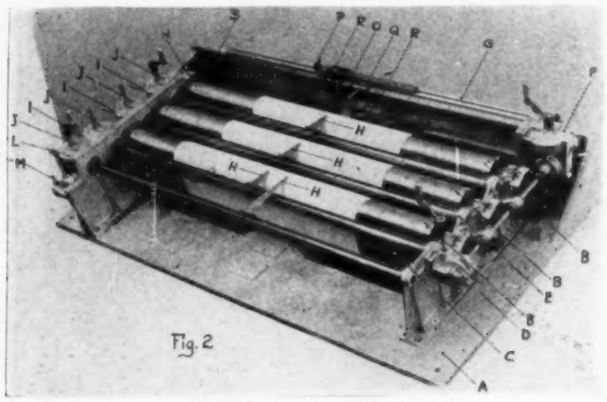
and a sample instrument has been manufactured for test. In the new instrument each set of curves for the different ballistic corrections is carried on a separate chart, which occupies the entire width of the board, thus permitting a much greater spread of the curves than does the Pratt Range Board. The tide and wind curves were placed on the same chart, since this could be done without increasing the size of the board. Each chart is mounted on two rollers, one above the other. The top of the roller is used to carry the part of the chart actually required for use. The lower roller keeps the chart tightly wound on the roller under spring tension.

The vertical scale of the chart is 1,000 yards equals one inch, and the horizontal scale is 200 yards equals one inch. The correction tape at the top of the board has a scale of 500 yards equals one inch. The correction board permits a total range correction of plus or minus 11,000 yards. The outside dimensions of the board are as follows: Length, 47 inches; height, 25 inches; thickness, 9 inches.

The rollers (B) are all geared to a common shaft (E), which can be rotated by the worm gear and handle at (D). This permits of all the charts to be set simultaneously at the given range. The adjustment is provided so that each roll may be adjusted slightly with respect to the common shaft.

The shaft (E) passes to the top of the board through the differential gear at (F) and carries a gear on which is mounted the range correction tape (G). Any movement of the rolls (B), therefore, produces a corresponding movement of the tape (G). The object of the differential gearing (F) is to provide a means of setting the tape without moving the rolls.

The range correction pointers (H) are carried across the charts by screws actuated by the cranks on the ends of the rods (I). When the cranks are used on the shafts (J), a faster movement of the pointers (H) is obtained. The movement of each of these pointers is transmitted individually to the screw at the top of the board, on which is mounted the total correction pointer (K). When each of the pointers (H) has been set at the proper correction curve, the sum of the corrections is indicated on the tape (G) by the pointer (K).



Range Correction Board

At (M) is shown a worm gear, which permits the total correction pointer (K) to be set independently of the pointers (H).

At (O) is shown the map range pointer. This consists of a scale arranged to slide from one end of the board to the other, which can be clamped at any desired position by the thumb nut (P). Opposite the center, or (O), of the scale is the fixed index (Q). The sliding index (R) is arranged to move along the scale.

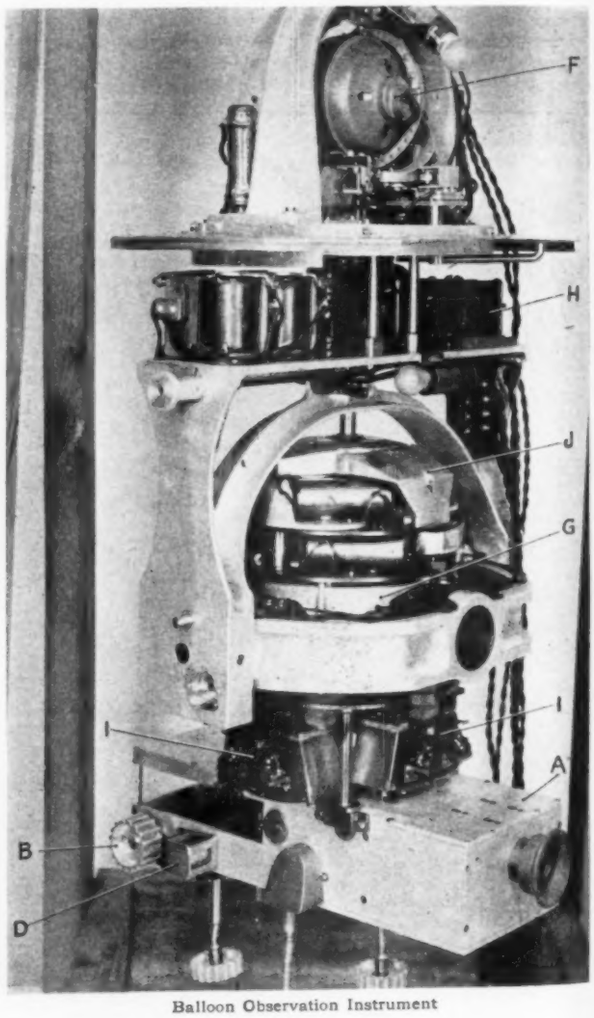
The method of operating the board is as follows: Set the proper range on the charts opposite the indexes at the right end of each of the front rolls by turning the worm (D). Set each of the pointers (H) at the normal of the corresponding set of curves. Set the tape at the proper range by moving the crank (F). Set each pointer (H) at the proper correction curve. The corrected range will then be indicated on the tape by the pointer (K). If the travel correction is put on, the corrected range may be read on the tape opposite the movable pointer (R) when the fixed pointer (Q) is set opposite (K).

Balloon Observation Instrument.

Due to the increased ranges at which the latest types of seacoast defense artillery are designed to operate, at which ranges the target would often be below the horizon as viewed from the usual base-end observing station, it has become necessary to provide stations at greater elevations than is practicable by the use of the present range-finding towers. The captive balloon is well adapted to use as an observing station, but since it is in continual motion, and often changes its position by hundreds of yards in a few minutes, no ordinary observing instrument can be used in it for taking observations with any degree of accuracy.

The observing instrument shown in the accompanying illustration was specially designed for use in a captive balloon, and one sample has recently been completed at Frankford Arsenal and shipped to Fort Monroe for test by the Coast Artillery Board. Two instruments were, in fact, manufactured, one consisting only of the observing element, shown at A in the illustration, designed to be held in the hands while observing, while the other, as shown in the complete illustration, is stabilized and is intended to be supported on the cross-bar above the basket.

The observing element A of this instrument consists of two separate optical systems mounted side by side under a single cover and arranged so that the two fields of view are combined in a single eyepiece, one system forming the upper half of the field of the eyepiece and the other the lower half. One optical system is arranged so that by rotating the knob, B, the line of sight may be rotated in a horizontal plane to bring into the field a target at any azimuth. The other system is arranged so that its line of sight may be rotated in a vertical plane under the action of the knob, C, so as to bring into the field an object or aiming point on the ground in the vicinity of the balloon. When the aiming point has been brought into the lower field and the knob, B, is rotated



Balloon Observation Instrument

to bring the target in the upper field into coincidence with the aiming point, somewhat as in a self-contained range finder, the horizontal angle between aiming point and target as measured at the balloon will be indicated by the counting device at D.

In case only one observing station is available, the instrument may be used as a depression position finder. To obtain any degree of accuracy in this case, it is, of course, essential that the observing element remain level. In the stabilized type, the leveling is accomplished automatically. In the hand type, a level vial, viewed through an aux-

iliary telescope, is used to determine the level position. Assuming the telescope body to be level, the angular depression of the target may be determined by rotating the knob, E, until the target appears on the horizontal dividing line between the two parts of the field, after which the angle of depression may be read on the indicator on the right side of the instrument.

In the stabilized instrument, two gyroscopes are employed to bring the observing element, A, back to its given position after having been disturbed by a motion of the balloon. The gyro, F, keeps the telescope trained in azimuth while the gyro, G, maintains it in the horizontal position. The general operation of these gyros is as follows:

When the instrument is rotated out of its original set position in azimuth, the gyro, F, which has maintained its original position, makes an electrical contact which causes the motor, H, to rotate and bring the telescope again to its position. When the telescope has gotten out of level, ball pendulums, located at I I, make contact, causing the lead weights, J, mounted above the gyro casing, to move in a certain direction. This has the effect of throwing the gyro system out of balance, hence the gyro takes on a precessional movement which is in the proper direction to cause the telescope to return to the horizontal position.

Power for driving the two gyros, for operating the motor, relays, magnets, etc., is obtained from a 32-volt storage battery forming part of the equipmnt of the instrument. Since the gyros require alternating current, it has been necessary to provide a motor generator to furnish it, and for this reason the total weight of the equipment (155 pounds) is greater than desirable. If a suitable D. C. gyro can eventually be developed it will aid materially in reducing the weight and complication of the device.

The instrument was designed with the idea that the azimuth stabilizing device should keep the target in the field of view at all times under moderate weather conditions, and that the horizontal gyro should, at the same time, maintain the level of the telescope very closely. Shop tests indicate that these purposes have been accomplished. For moderate swings in the instrument support, the target will always be found within the field of view. Since coincidence between the images of target and aiming point may be made at any point on the horizontal dividing line in the field of view, the instrument does not require to be stabilized more closely than as indicated. The horizontal gyro will maintain the level of the telescope within plus or minus 10 minutes of angle, under moderate disturbing forces, which accuracy is probably ample for all practical purposes in an instrument of this sort.

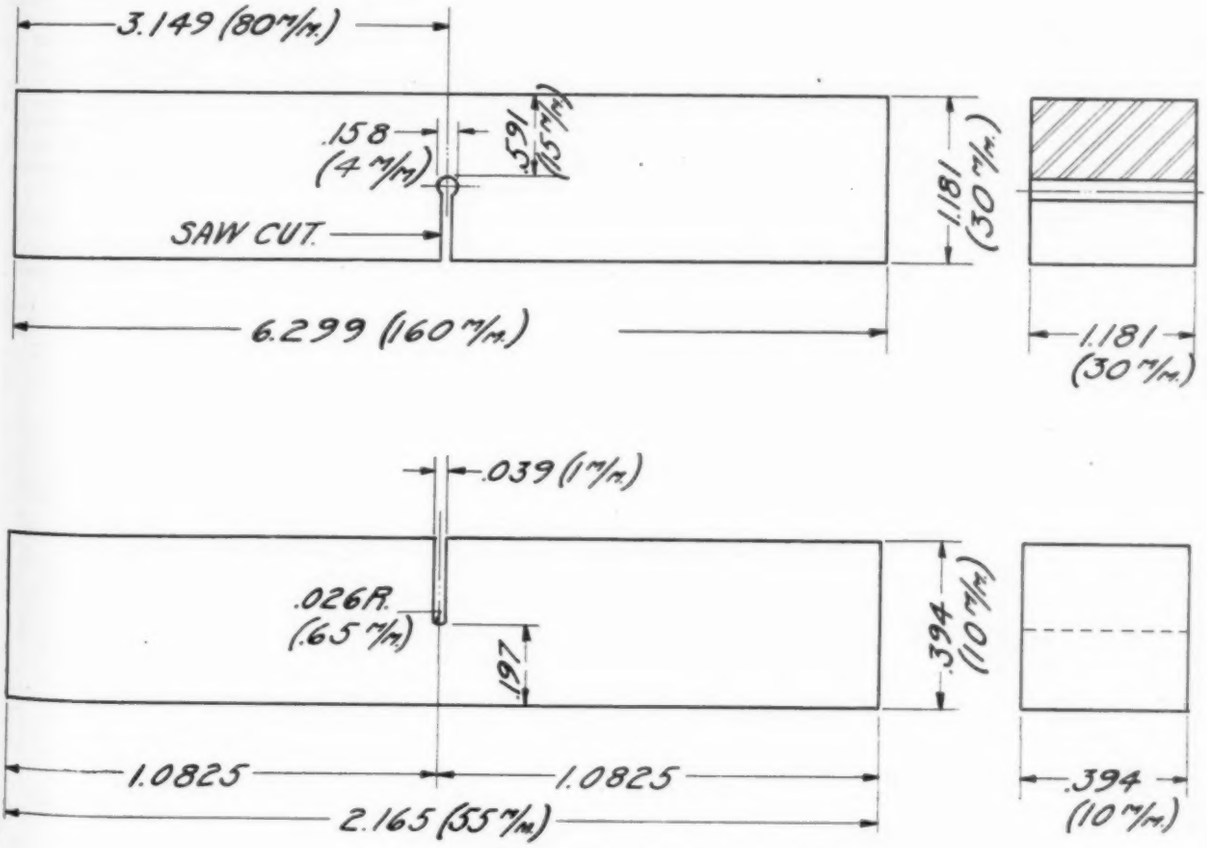
The forthcoming test of the stabilized and unstabilized instruments will indicate whether the advantages of the former are sufficient to warrant the expense and complication involved. It will also determine whether the principle involved in the observing instrument can be depended upon for accurate work under service conditions. The apparatus to be employed for balloon observation is capable of great development once the principles on which it should operate have been demonstrated.

WATERTOWN ARSENAL NOTES

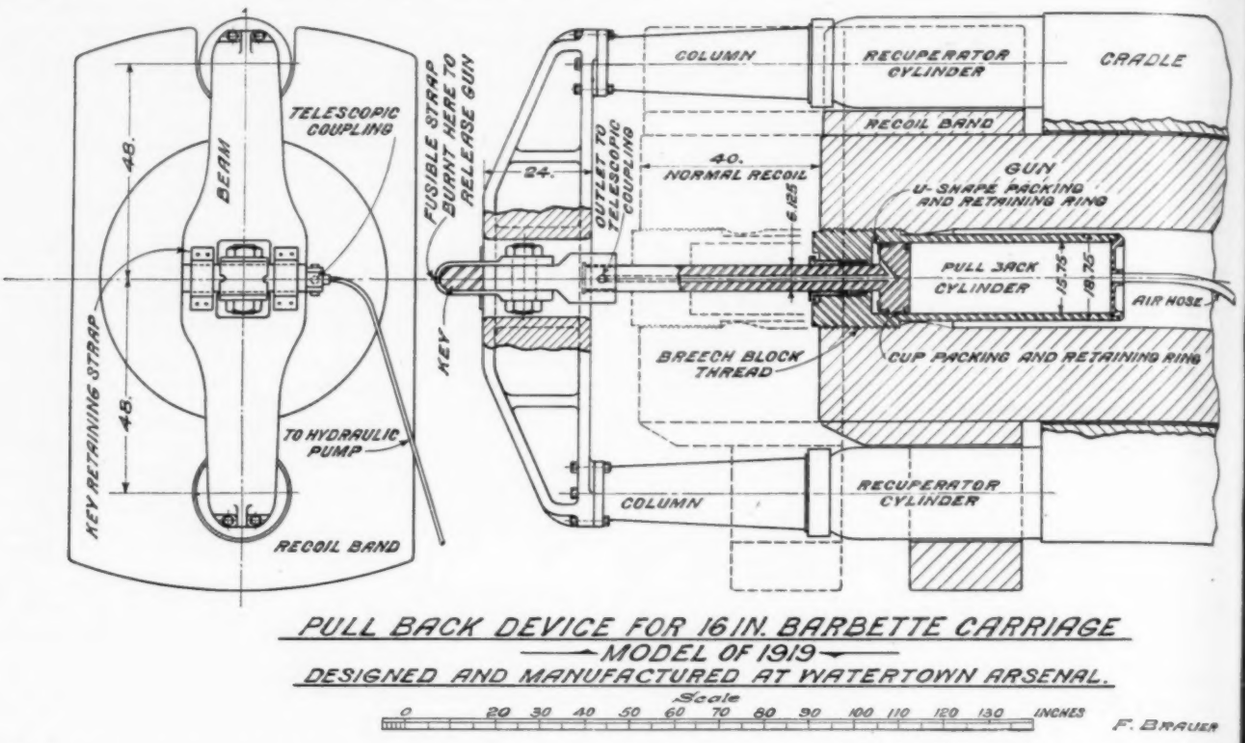
Charpy Impact Test Specimen.

Frequent requests have been received by the laboratory at Watertown Arsenal for drawings showing the type of transverse test-bar used in both the large and small Charpy impact machines. The upper sketch gives the dimensions of the test-bar used in the large 300-kilogrammeter machine. This type of test-bar was adopted directly from recommendations furnished by M. Charpy, and no modifications have been made.

For transverse impact tests on the small Charpy machine the notch and bar are as shown in the lower sketch. A slight modification has been made in this bar which allows the notch to be made with a milling tool, which gives the proper radius at the bottom without any drilling operation. It has been found by experiment that the additional material left on the shoulders has no effect upon the results obtained, while at the same time reducing the cost of preparation.



Dimensions of Test Specimens for Charpy Impact Machines
Upper sketch, 300 kilogrammeter machine. Lower sketch, small machine



PULL BACK DEVICE FOR 16 IN. BARBETTE CARRIAGE
MODEL OF 1919
DESIGNED AND MANUFACTURED AT WATERTOWN ARSENAL.

Scale 0 20 30 40 50 60 70 80 90 100 110 120 130 INCHES

F. BRAUER

Pull-Back Device for 16-inch Barbette Carriage.

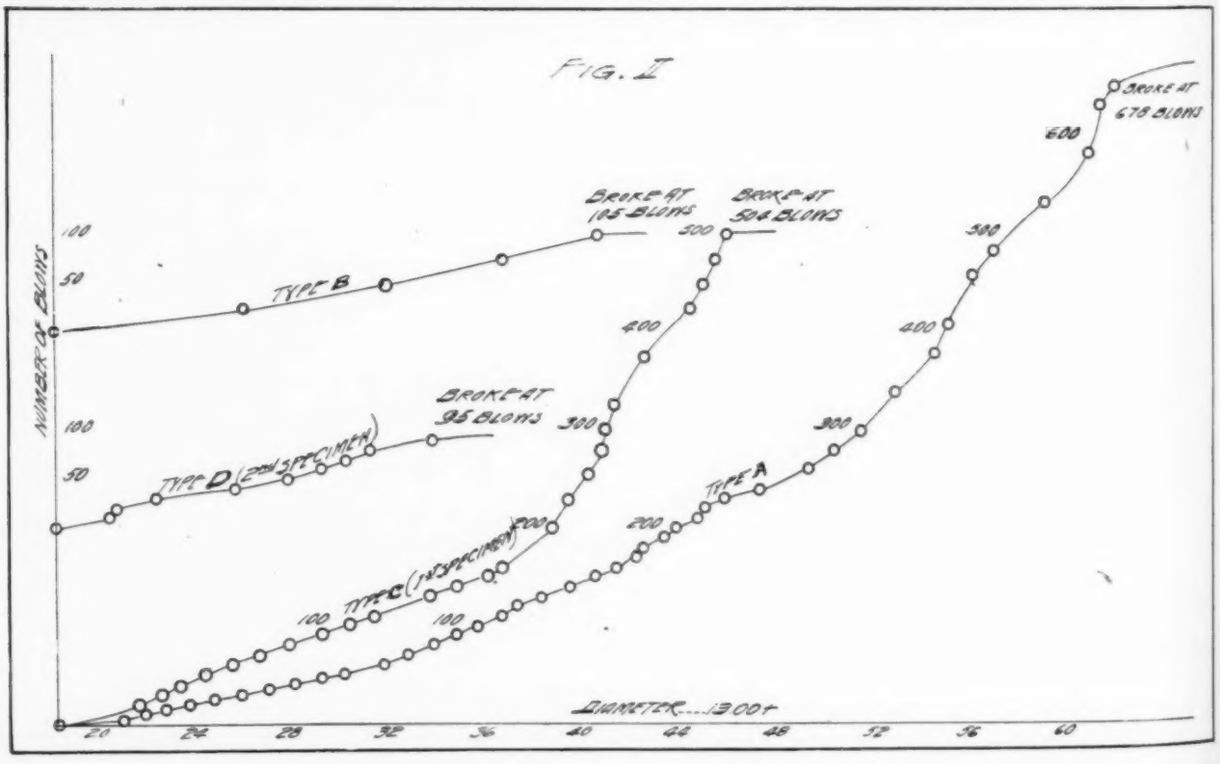
The pull-back device designed for the 16-inch gun on barbette carriage is shown in the diagram. This device was designed by Mr. Brauer, Chief Engineer, at Watertown Arsenal.

It is always very desirable to test the action of the gun in counter recoil at the place where the carriage is manufactured, in order that the buffers which control the action of the carriage in counter recoil can be adjusted. As it would be impossible to fire a gun of this size at the plant of the manufacturer, it is necessary to devise some means for pulling the gun into the recoiled position and to thus simulate the action of the gun during firing.

In the case of smaller guns and gun carriages, the gun is usually retracted by means of blocks and tackle or by means of a hydraulic cylinder and a special release mechanism.

In the case of the 16-inch 50-caliber gun and barbette carriage, a force of 800,000 pounds is required to pull the gun into the recoiled position against the compressed air in the recuperator system. A special device was therefore necessary.

This device consists of a hydraulic cylinder, which is screwed into the breech bushing thread of the gun, the cylinder extending into the powder chamber. A stationary beam is mounted upon two steel tubular columns which are securely screwed to the rear ends of the recuperator cylinders. The piston rod of the pull-back cylinder passes through a hole in this stationary beam and is secured to it by means of a steel



strap and key, as shown. The key is held in place on the stationary beam by means of steel straps.

To retract the gun, water is pumped into the pull-back cylinder through a hole in the piston rod. The stationary beam being connected to the cradle remains fixed, while the pressure of the water on the cylinder head forces the gun back against the pull of the recuperator cylinders. A telescoping coupling is mounted on the right side of the stationary beam connecting the pipe from the pump to the hollow piston rod, its purpose being to allow the piston rod to move ahead freely when the gun is released. To release the gun, the fusible strap is cut at the rear with an oxy-acetylene torch. This disconnects the piston rod from the stationary beam and allows the gun to go freely into battery. The two halves of the broken fusible strap are bent apart as they pass over the key and have no appreciable effect on the movement of the gun. The air hose is connected to the rear end of the pull-back cylinder and is used for supplying compressed air for forcing the piston rod into position for the next test.

With a pressure of 5,000 pounds per square inch in the cylinder, a force of 828,000 pounds is exerted on the beam, which is sufficient to retract the gun at zero degrees elevation. A lesser force is required for the greater elevations. This device was used for snapping the gun at zero degrees, 34 degrees and 65 degrees elevation and functioned satisfactorily.

Resistance to Shock.

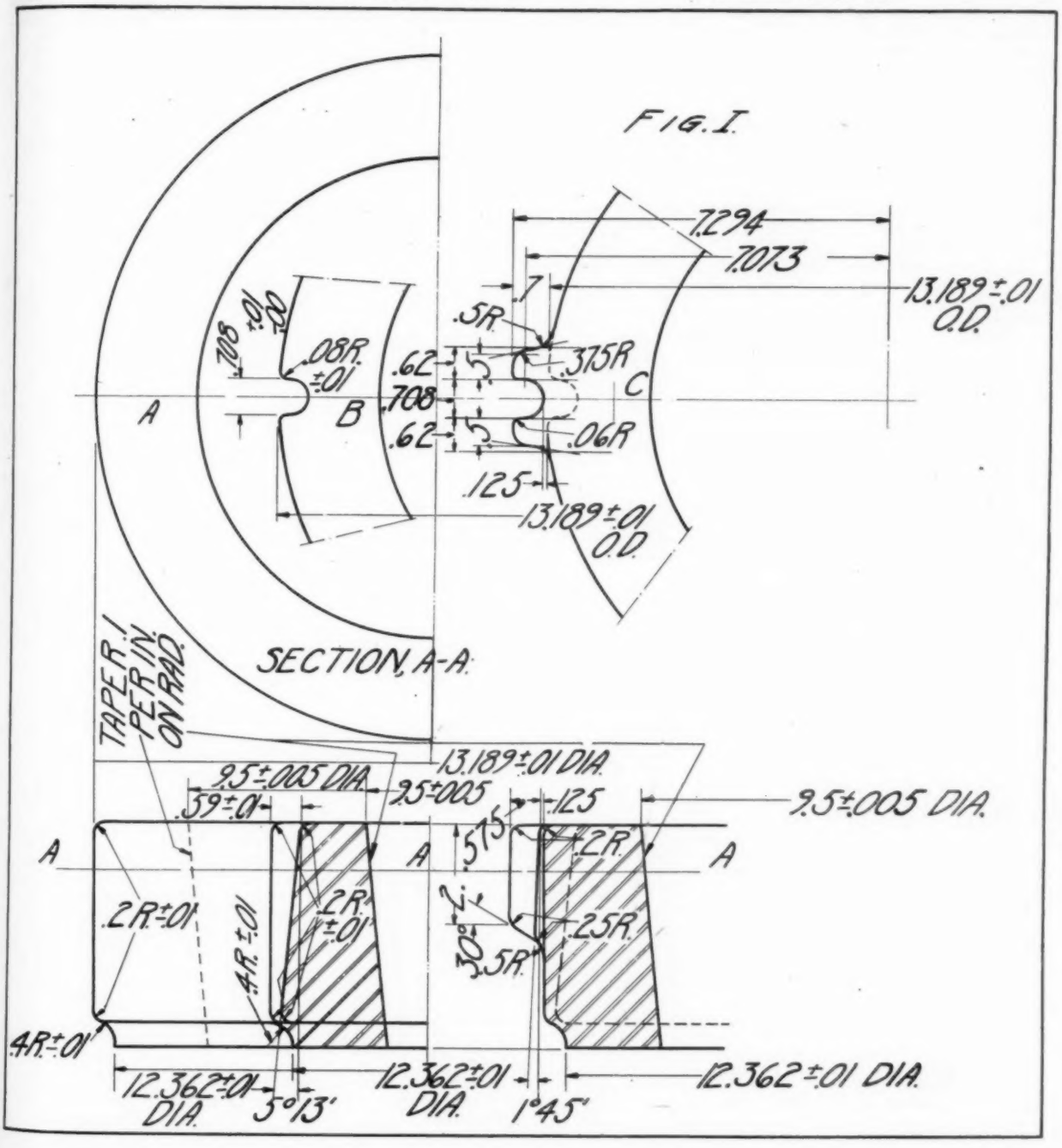
Tests have recently been concluded at the Watertown Arsenal which demonstrate in a striking manner the extent to which cylindrical sections of a shape similar to the muzzle end of guns are weakened by semi-circular grooves either cut into the cylinder or cut into lugs which have been welded on the cylinder.

Fig. 1 shows specimens used for making these tests. "A" is a hollow cylinder with a taper hole through the center, in which is placed a suitable wedge for receiving the blow of a 1,000-pound hammer dropped from a height of 36 inches; "B" is of the same dimension, except that a groove approximately .7 inch broad is machined in the outer surface; "C" is of similar construction, with the exception that metal has been welded on in a manner shown by the diagram.

In making the tests a 1,000-pound weight was dropped a sufficient number of times to cause rupture, the measurement of the diameter being taken after each blow.

Fig. 2 shows the relationship between the increase in diameter and

(Continued on Page 361)



AIRCRAFT ARMAMENT DIVISION

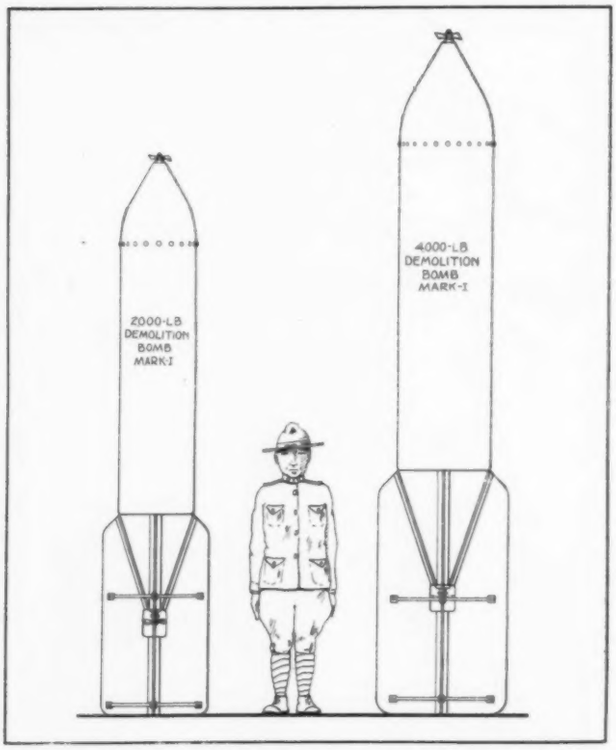
Aircraft Armament Activities

Bombs.

During the past month bombing activities at Aberdeen Proving Ground have been carried on quite intensively.

When it was thought that the trouble with the .05-second delay element had been overcome, it was found that this delay would not work in all bombs, the exception being in the 600-pound bomb when dropped on water. As bombs dropped on water could not be recovered, the trouble could not be definitely located except by a system of elimination. The peculiar part of the whole thing was that all the instantaneous primer detonators would function. Finally, by reducing the size of the shear wire in the nose fuses and the strength of the spring in the tail fuses, tests indicated that the bombs would function properly.

It is interesting to note that prior to this month the greatest weight of bombs dropped in one day was 9,800 pounds. Records kept for three days showed that 18,400 pounds were dropped in one day; 18,200 pounds the second day and approximately 10,400 pounds of bombs the third day or a total of 47,000 pounds. Those who have had any contact with bombing work during the war will be gratified to learn of the increase in efficiency of testing equipment which allows the dropping of this tonnage of bombs.



The New 2,000-pound and 4,000-pound Demolition Bombs—A 6-foot Soldier Standing Between

The 2,000-pound Bomb is a little over 13½ feet long and almost 19 inches in diameter. It will carry 1,000 pounds of explosive. The 4,000-pound Bomb is 13½ feet long and approximately 23 inches in diameter. It will carry one ton of explosive.

Metal parts of new bombs are already being shipped to Picatinny Arsenal for loading preparatory for use in the bombing maneuvers in which battleships are to be bombed. The promptness with which this material is being manufactured by the various arsenals is very gratifying.

The construction of the 2,000-pound bomb is well under way, and shipments are expected by May 15, 1921. Frankford Arsenal is fabricating these bombs as well as all fuses, and adapters which are to be used in all bombs. The arsenal is handling this work very creditably, although its capacity is being taxed to the utmost in the effort to turn out this material within the specified time.

Estimates are being obtained from Watertown Arsenal for the manufacture of a small number of 4,000-pound bombs. The contract for the construction of these bombs should be placed very soon.

Failures have been obtained in testing the 1,100-pound armor-piercing bomb. When the bombs were dropped, two duds were located and an attempt was made to recover them. These bombs were dropped from 4,000 feet and 8,000 feet, respectively. After digging down sixteen feet, water was encountered and the work had to be abandoned. It is therefore not known how much farther the bombs penetrated, but it is interesting to note that this bomb when dropped from 4,000 feet and 8,000 feet will penetrate this distance, and possibly deeper, into solid earth.

Work is progressing at the Bureau of Standards on the ballistic testing of bomb models in the wind tunnel. It is not possible to publish herein the results which are being obtained.

Since weather conditions at Aberdeen have been very unfavorable to the obtaining of ballistic films, it has been decided to install equipment for obtaining ballistic data on bombs by another method which will not give as complete information as the ballistic films, but which at least can be carried on without the necessity of waiting for the ideal conditions needed to obtain the ballistic films.

It is proposed to locate at Aberdeen two camera obscura buildings, and with them and the two towers which are now in place, obtain observations on an airplane just as a bomb is released, and also ascertain the point of impact of the bomb. By a proper arrangement of these stations, it will be possible to obtain the path of the airplanes just prior to release of the bomb, which will give ground speed and direction of flight, the location of the airplane at the instant of release, the direction and speed of the airplane after release, the direction and velocity of the wind and the altitude of the airplane. The point of impact will then be located with reference to the point of release, and the time of fall of the bomb will be obtained by appropriate timing apparatus. With these facilities it is hoped to progress more rapidly on the investigation of bomb ballistics.

Bomb Sights.

A great deal of work is being done on the development of stabilizers for bomb sights. Practically all new sights that are now under development are stabilized by some form of gyroscopic stabilizer. There are three different stabilizers under development, called the Mark VIII, Mark X and Mark XII. The Mark VIII is practically completed. The Mark X has had to be modified to a certain extent, but will be completed shortly. The Mark XII is still under development, and it is expected to incorporate in it the most advanced features developed during the work on the Mark VIII and X stabilizers. Capt. E. J. Loring and Dr. Lucian have worked out some very ingenious means of damping out the precession of the gyros. It is expected that in a future issue of ARMY ORDNANCE Captain Loring will describe the developments under way on bomb sights. In view of the probable transfer of development of bomb sights to the air service, it is possible that this department will not be able to test the sights and stabilizers which have been developed and that these will be transferred in their present condition to the air service. This is one of the activities which, by General Order No. 6, W. D., 1921, must be transferred to the air service by June 30, 1921.

Bomb Racks.

Preparations are being made to turn over the development of bomb racks to the air service on June 30, 1921. This is also one of the items which, under General Orders No. 6, W. D., 1921, is to be transferred to the air service for development. Orders for bomb racks, however,

will be continued to be handled by the Ordnance Department up to June 30, 1921, and recently a request for more of the Mark XVIII Racks to equip new pursuit planes under order has been received from the air service.

Further tests of the Mark XVIII Racks have demonstrated that they are quite satisfactory and far superior to the old Mark V release mechanism.

New bomb racks are under development for a giant bomber which the air service is having constructed. The capacity of these racks will be approximately 4,000 pounds. It will be interesting to note that in this design it is planned to carry four 1,100-pound demolition bombs inside the fuselage. This is quite an advance over the old method of carrying large bombs under the wings or under the fuselage.

Aircraft Machine Guns.

The testing of the new .50-caliber aircraft machine gun is continuing. The gun in a recent test was fired in the air quite successfully. The progress on this gun has been sufficiently satisfactory to indicate that the project for modifying the 11-mm. Vickers Gun may be dropped, as it is believed that the .50-caliber is quite superior to the 11-mm. Vickers, with its higher muzzle velocity and greater weight of bullet.

Work is progressing on the speeding-up device which is to be attached to the Lewis Aircraft Machine Gun. There is every indication that the Lewis Gun can be speeded up quite satisfactorily.

Tests have been held by the Air Service with the .30-caliber Browning Aircraft Machine Gun with a view of using it as an observer's gun. In the preliminary tests, quite satisfactory results were obtained. It will be appreciated that if the same gun can be used as a free gun as well as a fixed gun, this will considerably simplify maintenance of machine guns as well as supply and manufacture.

The 37-mm. Baldwin Automatic Aircraft Gun, which had been undergoing test at Aberdeen Proving Ground and the Bureau of Standards, was finally worn out through firing and returned to Springfield Armory, where a new gun is now being completed. It is planned to include in this new gun all modifications which were worked out in the old gun, and subject the new gun to an exhaustive firing test. The final results obtained with the modified Baldwin Gun, although not entirely satisfactory, were a decided improvement over what had been obtained in the first part of the tests. It is believed that the testing of the gun will be held the latter part of May. The Colt Patent Fire Arms Manufacturing Company are giving careful consideration to the development of a 37-mm. aircraft machine gun, but have not yet definitely indicated their willingness to proceed with the work.

Artillery Division Notes

(Continued from Page 359)

the number of blows struck. Curve "A" representing the unnotched specimen; "B" the notched specimen; "C" the welded specimen of good welding characteristics, and "D" the same, but of a poor weld. It is interesting to note that the relationship between number of blows and increase in diameter is practically constant up to 100 applications of the load. At this point, however, it will be noted that failure occurred in two of the specimens, while in the other two the rate of change in diameter decreased for a given number of blows.

The results from these tests seem to show that the welding of guns made near the muzzle is a questionable procedure unless the highest quality of results can be guaranteed; also, that notches or similar indentations weaken the section very appreciably.

The Watertown Arsenal Foremen's Association was organized April 23, 1919, and has had a very successful growth. Its object is the promotion of good fellowship and advancement of knowledge and to promote social, fraternal and technical relations of its members. It stands ready at all times to welcome speakers who can enlighten the members on their work and add to their efficiency and co-operation.

The Watertown Arsenal Foremen's Association early recognized the value of the Army Ordnance Association and became connected with it by the appointment of seven members and purchasing memberships for selected leaders of the supervising staff of the arsenal.

At our annual banquet early in 1920, Gen. C. C. Williams, Chief of Ordnance, was our guest, with Col. G. F. Jenks, both of whom talked interestingly on the work of the department.

Later in the year, Col. E. M. Shinkle gave a most interesting lecture, which was splendidly illustrated, on the subject of projectiles.

Another banquet was held in January, 1921, at which the guest of honor was Col. C. M. Wesson, head of the Bureau of Industrial Relations of the Ordnance Department.

Still another of our guests was Gen. C. B. Wheeler, who gave us a talk on his service in France.

Maj. G. M. Barnes, of the Artillery Division, Railway and Seacoast Carriage Section, was also a guest of the Association, and gave a very interesting lecture on development of ordnance, especially railway ordnance.

The Association held a Ladies' Night, Saturday, April 16, 1921, in the cafeteria at the arsenal. The building was specially arranged for the occasion, and the entertainment was varied.

A number of prize dances were held, the winners being rewarded with gold pieces, boxes of candy, flowers, etc. The Commanding Officer, Gen. T. C. Dickson, Lieut. Col. G. L. Wall, Works Manager, and Maj. W. M. Myers, Superintendent of the Mobile Carriage Department, were among the guests, and entered into the contests with spirit.

The representatives of the Foremen's Association in the Army Ordnance Association are:

Mr. F. Brauer, Chief Draftsman; Dr. F. C. Langenberg, of the Testing Laboratory; Mr. A. H. Lawe, of the Planning Department; Mr. G. F. Laughran, of the Woodworking Department; Mr. C. E. Barba, of the Seacoast Carriage Department; Mr. Nelson, of the Maintenance Department; Mr. Sampson, of the Foundry.

Test of Semi-Automatic Shoulder Rifles

(September 15, 1921.)

Rapidity of fire has been one of the important considerations affecting the design of small arms since the very beginning of their use. Attempts were made to adopt the breech-loading principle as long ago as 1664, when the first English patent for a breech loader was issued to Abraham Hall. In 1807, the Rev. Alexander Forsyth, a Scotch clergyman, patented the percussion system of igniting the charge of powder. Later, about 1821, appeared the percussion cap, which is variously attributed to Jos. Shaw, Philadelphia, and Jos. Egg and Joe Manton, of London.

It was not, however, until the perfection of the gastight cartridge, containing its own means of ignition, following the invention of the pin-fire cartridge by Houiller, of Paris, in 1847, that the breech loader became a practicable possibility. During the next 20 years there appeared various types of single-shot rifles on the breech-loading principle, and among repeaters the Winchester and Spencer, which were quite celebrated at that early day.

The Swiss were pioneers in the application of the repeating principle to military use, and in 1869 the re-arming of their troops with the Vetterli rifle was authorized. It was not until 1885 that magazine arms were issued to the German army, which example was rapidly followed by all the great powers.

Meanwhile, in 1883, the invention of the automatic machine gun by Hiram Stevens Maxim pointed the way to a still greater possibility of rapid fire.

Immediately following the perfection of the automatic machine gun, an application of the principle to shotguns, rifles and pistols was attempted. Considerable success has been obtained in the design of pistols, and the standard service arm of this type now in use in the United States Army is known as the automatic pistol, Model 1911. It may be of interest to note here that what is generally spoken of as the "automatic system" would be more correctly described as the "self-loading" or "auto-loading system," because the real automatic gun performs the function of firing, as well as reloading the piece.

In general, self-functioning and automatic arms are operated in three ways: By the blow-back of the gas against the head of the bolt; or by a gas-operated piston, which operates the bolt in turn; or by the force of recoil.

With regard to the blow-back system, many automatic pistols are designed after this plan, but it is hardly practicable for use with cartridges of high intensity. The gas-operated and recoil-operated systems have been utilized successfully in the Browning types of machine guns and automatic rifles, also in the Remington self-loading rifle, which is now on the market in sporting form. These systems require considerable apparatus for the purpose of unlocking the bolt, thus making necessary an additional weight, which performs no useful function after the actual unlocking is accomplished.

The rifle cartridge, Model 1906, which is now the standard service ammunition in the United States, gives a chamber pressure of 52,000 pounds per square inch. This pressure produces a high degree of heat and, consequently, in rapid fire the barrel of any small arm using this cartridge will be heated to such a point as to make its use dangerous, unless some means of cooling during firing is provided. Thus we see in the machine gun either a very heavy barrel with radiating vanes, as in the Hotchkiss, or a water jacket as in the Browning and the Maxim. Again, the stresses in working parts of a self-functioned arm are large. Thus this requires a strong and sturdy design for use with a cartridge of such great intensity. It is therefore a difficult problem to keep the total weight within proper limits.

Prior to the World War, machine guns were looked on as auxiliary, rather than principal weapons, and it was considered that the ammunition for the infantry rifle would be satisfactory for this type also. The trend of rifle development has been toward the smallest practicable caliber and the lightest ammunition consistent with long-range infantry

fire. The war has shown us that the machine gun is one of the most important means available for attack and defense, and that it is capable of performing the function of long-range fire better than can infantry, with the result that there is a growing tendency to regard extreme range in the rifle as unnecessary.

As was noted, there may be some divergence between the requirements for a machine gun and for an infantry rifle, as indicated by the lessons of the war. If we can accomplish all the results thought necessary by means of long-range infantry fire with the machine gun, we may then reduce the caliber of the shoulder rifle and the pressure and corresponding recoil and heating effect of the cartridge. Such a course would undoubtedly aid materially in the solution of the problem of producing a semi-automatic rifle of usable weight, and still having sufficient sturdiness and strength to stand the rough usage to which a military arm is subjected. With this point in mind, it will be noted in the specifications that the rifle desired may be adapted to function with cartridges of .25 caliber, of good military characteristics, and the rifle itself being of simple and rugged construction.

In this matter the Ordnance Department of the Army has not been backward in attempts to reach a solution. Other governments have experimented with many types and designs, but up to the present time, none has been successful. In our own service the matter dates back to 1902, when we note in the report of the Chief of Ordnance of that year that "The only radical improvement which is known to be under study in muskets is the application to these arms of the automatic principle to the extent of causing the musket itself to effect its own reloading upon discharge."

Competitive trials are planned by the Ordnance Department to be held about September 15, 1921, in which it is hoped that a number of rifles will be submitted and compared with a view to finally obtaining a suitable arm of this type.

Auto-loading Rifle

In order to provide a means for judging the tactical possibilities of the auto-loading rifle of rather smaller caliber than the present service arm, provision has been made by the Ordnance Department to forward to Camp Benning, Georgia, for test by the Infantry School, a number of Remington Auto-loading Rifles, Caliber .25, modified by the addition of a Lyman No. 48 sight with short shank, which has been changed so as to fit on the right-hand side of the rifle in such a position as not to interfere with either the safety or trigger finger.

This sight has not been built for the Model 8A Remington, and, consequently, the peep does not come quite in the center. This feature has been taken care of by offsetting the front sight a corresponding amount.

A new front sight of military type, with blade .08-inches wide has been fitted. A new forearm of military type has been provided. An upper band for the Springfield rifle was modified to fit this rifle and was used for attaching a sling swivel. The rear sling swivel was attached to the butt in the proper place. The addition of a standard sling completes the changes in this arm.

As a result of the tests which are to be held, it is hoped to obtain some definite data concerning the tactical advantages which may accrue from the use of such a type weapon.

French Gun with 200-Mile Range

Interesting tests of what is claimed to be a gun which may have a range of 200 miles, the invention of Lieut. Col. Maze, of the French army, were recently made on a model in miniature at the Belgian artillery range at Vivegnis, near Liege, before a number of French and Belgian staff officers and artillery experts, says a dispatch from Paris to the *Chicago Tribune*. The inventor claims a 300-kilometer range as against the 125-kilometer range registered by the German "Big Bertha" in the bombardment of Paris from the St. Gobain forest in November, 1918. The first tests, which continued for six days, were held near the end of December. The small model used as a testing gun was built along special lines, with the caliber of the French 3-inch piece. Colonel Maze has named the gun "Turbo," because, turbine-like, the velocity of the projectile increases as the range grows greater The remarkable range of the gun is claimed to be due to three factors: The nature of the explosive used, the gun itself, and the character of the projectile. One of the striking characteristics of the piece is its equal thickness from breech to muzzle. Improvements and refinements of the shell, it is claimed, reduce resistance, giving increased range with the same initial velocity. This is made partly possible through a sharp-pointed nose and a flattened end, thus resembling the shell used by the "Big Bertha." The special barrel used is capable of withstanding a pressure of 3,000 kilograms per square centimeter. The dispatch states that discovery of a certain explosive, which continued to exert its maximum pressure until the shell left the gun, influenced the construction of the "Big Bertha," which type of gun, it is added, has now been further developed in the "Turbo," after experiments with and close study of the German gun. French and Belgian authorities are represented as endeavoring to keep particulars of the new piece of ordnance secret, despite Article VIII of the Covenant of the League of Nations, wherein the signatories are pledged to inform each other concerning their armament.— *Army and Navy Journal.*

Allerton S. Cushman
A. M., Ph. D.
(Ex-Lt. Col. Ord., U. S. A.)
In charge of chemical activities and explosive dry houses, Frankford Arsenal, 1917-1918.
Consulting Chemical Engineer and Metallurgist
In charge Industrial Research Laboratories
Reports on metallurgy, coal, petroleum, explosives, dyes, foods, drugs, etc.
1845 B Street, N. W. Washington, D. C.

James A. Drain Dale D. Drain
DRAIN & DRAIN
Attorneys at Law
Wilkins Building, 1512 H Street
Washington, D. C.

Rogers Birnie Wilford J. Hawkins
Birnie & Hawkins
Ordnance and Industrial Consulting Engineers
511 Fifth Avenue New York

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